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THE PLOTTING OF MAPS ON A CRT PRINTER

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TABLE OF CONTENTS

ABSTRACT

Files of map data have been recorded to cover the World, the United States, and the Potomac Area. A computing subroutine has been prepared to plot the map data on the Naval Ordnance Research Calculator.

FOREWORD

The work which is covered by this report was performed in the Mathematical Physics Branch under the Foundational Research Program of the Naval Weapons Laboratory, Task No. R0110101. Assistance in map reading was contributed by Mrs. J. Thompson. Checkouts of data were performed by W. H. Langdon. The date of completion was 6 May, 1963.

APPROVED FOR RELEASE:

/s/ R. H. LYDDANE
Technical Director

INTRODUCTION

Much of the labor which goes into the preparation of a map could be saved through the use of a cathode ray tube printer. This is especially true where a small quantity of information is to be displayed against an outline background. Maps which are utilized in weather forecasting and in space surveillance are examples of such applications. An irregular outline is presented in the cathode ray tube as a sequence of short line segments, which can be plotted with quantitative accuracy in the latest printers. Each line segment terminates at points which are derived from a file of map coordinates. The preparation of a file of coordinates requires a large amount of map reading, but after an initial investment in a digitalization of map data, any further processing can be automatic.

If only a few data are to be recorded, it is possible to read positions from a Mercator projection with paper scales at the rate of one datum per minute. For a large number of data, it would be advisable to use a mechanical reading aid which would record automatically in digital form the position of a reticle. The operator would be required only to keep repositioning the reticle and mistakes in recording would be minimized.

To illustrate the use of cathode ray tube printers in the plotting of maps, files of map data have been recorded and computing subroutines have been prepared at the Naval Weapons Laboratory. It is the purpose of this report to catalogue the available data and to document the existing subroutines.

The Naval Ordnance Research Calculator has been used in the preparation of representative maps. The NORC does thirteen decimal digit arithmetic at the rate of 15000 operations per second in response to three address instructions.

The CRT printer is connected on line to NORC. Although this printer is satisfactory for routine work, better results can be obtained in more recent installations where there is less distortion in the picture tube. The NORC printer can plot only dots, whereas modern printers can plot a segment in a single sweep of the cathode ray beam. How best to plot a line segment with dots is a problem, and two systems have been tested. In the first system, a dot was placed at each end of the segment and dots were distributed at equal distances between the ends, but this made the strength of line especially heavy for short segments and eliminated the gaps in dotted lines. In the final system, the dots are situated at uniform distances along the length of the entire contour, and the ends of line segments are straddled by dots.

ANALYSIS

Reliable sources of map data include (a) Hydrographic World Chart (Mercator Projection). (b) U. S. Geological Survey Maps (Transverse Mercator Projection). (c) World Aeronautical Charts (Lambert Projection). (d) National Geographic Maps (Polar Projection). (e) Lists of Maritime Positions (Bowditch).

The selection of datum points from these maps was founded upon the following objectives.

(1) To approximate shore lines with digital data in such a way that the fineness of detail is uniform over the surface of the earth.

(2) To approximate shore lines with polygons between datum points in such a way that the scaling may be increased substantially without loss of characteristic appearance.

An irregular coastline presents a choice of alternative polygons. Alternative choices are (a) a polygon which illustrates the major

characteristics of the shore line, (b) a polygon outside of which there is nothing but navigable water, (c) a polygon within which there is nothing but traversable land.

The fineness of detail is dictated by the requirement that the plotted line shall appear uniform in thickness. Any detail finer than the diameter of the plotting dot would be lost within the thickness of line. The change of direction at each corner of a polygon is usually less than 60° unless a larger angle is required for character identification of the shore line. A zigzag with larger deflections would merely thicken the plotted line. Any inlets, promontories, or islands of width less than the usual distance between datum points are bypassed. South sea islands which form open archipelagos are exceptions to the above rules.

All position data are recorded uniformly as geodetic latitude and longitude. The data are expressed in degrees, minutes, and seconds because these units are most common. There are many transformations for mapping the earth's surface on a plane sheet[1, 2]. A simple conformal transformation without correction for ellipticity of the earth has been selected to demonstrate the mapping data in the present report. The conformal mapping of a sphere upon a plane can be derived easily from a consideration of directions of corresponding elements.

In the case of a conical projection (Lambert), the map can be rolled up into a cone which is tangent to the sphere at a parallel of latitude. Let the latitude and longitude ϕ, λ be the coordinates of a point on the sphere, and let the origin of the map be situated at the latitude and longitude ϕ_0, λ_0 on the line of tangency. The

distance r_0 from apex of cone to line of tangency on a sphere of radius a is given by the equation

$$r_0 = \frac{a}{\tan \phi_0} \tag{1}$$

The apex angle θ for the point at position ϕ, λ is given by the equation

$$\theta = \sin\phi_0 \, (\lambda - \lambda_0) \tag{2}$$

and the apex distance r to the point is related to the latitude ϕ of the point by the condition of conformality,

$$\frac{dr}{r d\theta} = - \frac{d\phi}{\cos \phi \, d\lambda} \tag{3}$$

Substitutions from Equations (1) and (2) into Equation (3) and integration lead to the equation

$$r = \frac{a}{\tan \phi_0} \left[\frac{(1 + \sin \phi_0)(1 - \sin \phi)}{(1 - \sin \phi_0)(1 + \sin \phi)} \right]^{\frac{\sin \phi_0}{2}} \tag{4}$$

The Cartesian coordinates x, y of the point in the map are given by the equations

$$x = r \sin \phi \qquad\qquad y = r_0 - r \cos \phi \tag{5}$$

where x represents the easting and y represents the northing.

In the case of an axial cylindrical projection (Mercator), the equation of conformality becomes

$$\frac{dy}{dx} = + \frac{d\phi}{\cos \phi \, d\lambda} \tag{6}$$

This equation can be integrated to give the equations

$$x = a\lambda \qquad\qquad y = - \frac{a}{2} \ln \left(\frac{1 - \sin \phi}{1 + \sin \phi} \right) \tag{7}$$

where the origin of longitude is placed at the Greenwich meridian.

In the case of a transverse cylindrical projection (Transverse Mercator), the Cartesian coordinates x, y are related to transverse latitude and longitude ϕ', λ' by the equations

$$x = - \frac{a}{2} \ln \left(\frac{1 - \sin \phi'}{1 + \sin \phi'} \right) \qquad\qquad y = a\lambda' \tag{8}$$

which are derived from Equations (7) by interchange of variables. In accordance with spherical trigonometry, the transverse angles ϕ', λ' are related to the polar angles ϕ, λ by the equations

$$\sin \phi' = \cos \phi \sin(\lambda - \lambda_0) \qquad \tan(\phi_0 + \lambda') = \frac{\tan \phi}{\cos(\lambda - \lambda_0)} \tag{9}$$

where the angles ϕ_0, λ_0 are the coordinates of the origin of the map.

MAP PLOTTING ROUTINE

Operation

The routine plots map data within a specified area on the CRT printer.

Formulation

Each datum point in the map is specified by a 16-digit word on tape. The datum word is divided into 4-digit fields as follows.*

(a) First 4 digits → degrees of latitude

(b) Second 4 digits → minutes of latitude

(c) Third 4 digits → degrees of longitude

(d) Fourth 4 digits → minutes of longitude.

The first digit of each four digits specifies the sign as follows

(a) 0 → (+) sign (b) 1 → (-) sign

and the sign specifies the direction as follows

(a) N latitude is designated positive

(b) E longitude is designated positive

(c) W longitude is designated negative

(d) S latitude is designated negative.

The form of datum word has been selected so as to facilitate the direct recording of data from maps and gazetteers and the efficient conversion of the data to NORC numbers by an extraction mill.

The consecutive data for a continuous line segment run counter clockwise from the westernmost point. The file of data for a continuous line segment is terminated by a row of sevens.

*A sample datum word is 0022 0030 1120 1000 which designates a point at 22° 30′ N latitude and 120° 00′ W longitude.

The complete file of data for a map is arranged in accordance with two independent systems. (a) The consecutive data are arranged in a continuous sequence interspersed with rows of sevens. (b) The consecutive data are distributed over a sequence of blocks of arbitrary length and arbitrary block number. The blocks are never more than 100 words in length and the blocks are numbered in intervals of ten to permit the insertion of blocks of additional data.

The mapping routine reads map data from the input tape and converts the data to degrees of latitude and longitude. The mapping routine transfers control to a conversion routine. The conversion routine converts the latitude and longitude of any datum point into the map coordinates of the datum point. The conversion routine is a separate program of any length and may express any form of mapping projection. The conversion routine returns control to the mapping routine. Although the mapping routine is designed primarily to work with data which are expressed in degrees and minutes, it will work equally well with data which are expressed in minutes and seconds. The factor for converting minutes into decimal parts of a degree is the same as the factor for converting seconds into decimal parts of a minute.

The mapping routine compares the distance between datum points in a pair of consecutive datum points with a minimum limit. If the distance is less than the limit, the second datum point is bypassed in favor of subsequent datum points. The mapping routine plots only those datum points whose map coordinates fall within a predetermined area. A line segment may be terminated whenever the conversion routine replaces the x map coordinate by a row of sevens. Otherwise the plotting is confined to a specified rectangular area. The positions of a pair of consecutive datum points are sensed relative to the edges of the specified rectangular area. If both

datum points lie within the rectangular area, they are connected by a straight line. If they straddle the edge of the rectangular area, the datum point on the outside is moved to a point on the edge through linear interpolation between the datum points. If both points lie outside the rectangular area, the plotting is bypassed altogether. No page overflow occurs unless the rectangular area extends outside the printer field.

The camera selection and the symbol selection are under the control of the standard *P*-field options of the CRT printer. The continuity of line is under the control of a format word which designates the number of dots in each dash or space.* The routine plots dashes and spaces serially, beginning with the left digit pair in the format word and ending with the right digit pair. The routine skips blank assignments and recycles the format as long as the plotting of a line segment continues.

The routine continues to plot until an *EOF* is sensed on the input tape.

The following algorithmic statement can be utilized as a basis for the preparation of mapping routines for computers other than NORC.

MAPPING ROUTINE

Specifications

H_1 in loc H, H_2 in loc $H + 1$, V_1 in loc V, V_2 in loc $V + 1$
X_1 in loc X, X_2 in loc $X + 1$, Y_1 in loc Y, Y_2 in loc $Y + 1$

$$X_1 \rightarrow \frac{X_1 - H_1}{H_2 - H_1} \qquad X_2 \rightarrow \frac{X_2 - H_1}{H_2 - H_1} \qquad Y_1 \rightarrow \frac{Y_1 - V_1}{V_2 - V_1} \qquad Y_2 \rightarrow \frac{Y_2 - V_1}{V_2 - V_1}$$

*For example, the format word 9900 0000 0000 0000 plots a continuous line, while the format word 0102 0000 0000 0000 plots dots interspersed with spaces equivalent to two dots.

Read Input

(1) $k \rightarrow 0$

(2) Bypass to (9)

(3) $x_1 \rightarrow x_2$ (unmodified)

(4) $y_1 \rightarrow y_2$ (unmodified)

(5) Bypass to (7)

(6) $k \rightarrow 0$

(7) $i \rightarrow i + 1$

(8) If $i \leqq N$, bypass to (13)

(9) Read datum block

(10) EXIT for EOF

(11) Store N

(12) $i \rightarrow 0$

(13) For 7's, recycle to (6)

(14) $Q_1 \rightarrow 100 \times (PQ) + 1\frac{2}{3} \times (R)$

(15) $Q_2 \rightarrow 100 \times (S) + 1\frac{2}{3} \times (T)$

Convert Coordinates

(16) Q_1 in loc Q (latitude)

(17) Q_2 in loc $Q + 1$ (longitude)

(18) Refer to conversion routine

(19) P_1 in loc P (horizontal)

(20) P_2 in loc $P + 1$ (vertical)

(21) For 7's, recycle to (6)

(22) $x \rightarrow \dfrac{P_1 - H_1}{H_2 - H_1} = x_2$

(23) $y \rightarrow \dfrac{P_2 - V_1}{V_2 - V_1} = y_2$

(24) Store x_2 (unmodified)

(25) Store y_2 (unmodified)

Sense Border

(26) $k \rightarrow k + 1$

(27) If $k \neq 1$, bypass to (34)

(28) $p \rightarrow \dfrac{1}{719.4}$

(29) $q \rightarrow 0$

(30) If $X_1 \leqq x_2 \leqq X_2$ and $Y_1 \leqq y_2 \leqq Y_2$ go to (36)

(31) $F \rightarrow 0$

(32) Recycle to (3)

(33) Store $x_2 - x_1$, $y_2 - y_1$

(34) If $(x_2 - x_1)^2 + \left(\frac{y_2 - y_1}{1.2}\right)^2 < \frac{1}{(719.4)^2}$,
recycle to (7)

(35) If $x_1 < X_1$ and $x_2 < X_1$,
recycle to (3)

(36) If $x_1 < X_1 < x_2$,

$$x_1 \rightarrow X_1$$

$$y_1 \rightarrow \frac{(x_2 - X_1)y_1 + (X_1 - x_1)y_2}{x_2 - x_1}$$

(37) If $x_2 < X_1 < x_1$,

$$x_2 \rightarrow X_1$$

$$y_2 \rightarrow \frac{(x_2 - X_1)y_1 + (X_1 - x_1)y_2}{x_2 - x_1}$$

(38) If $X_2 < x_1$ and $X_2 < x_2$,
recycle to (3)

(39) If $x_1 < X_2 < x_2$,

$$x_2 \rightarrow X_2$$

$$y_2 \rightarrow \frac{(x_2 - X_2)y_1 + (X_2 - x_1)y_2}{x_2 - x_1}$$

(40) If $x_2 < X_2 < x_1$,

$$x_1 \rightarrow X_2$$

$$y_1 \rightarrow \frac{(x_2 - X_2)y_1 + (X_2 - x_1)y_2}{x_2 - x_1}$$

(41) If $y_1 < Y_1$ and $y_2 < Y_1$,
recycle to (3)

(42) If $y_1 < Y_1 < y_2$,

$$y_1 \rightarrow Y_1$$

$$x_1 \rightarrow \frac{(y_2 - Y_1)x_1 + (Y_1 - y_1)x_2}{y_2 - y_1}$$

(43) If $y_2 < Y_1 < y_1$,

$$y_2 \rightarrow Y_1$$

$$x_2 \rightarrow \frac{(y_2 - Y_1)x_1 + (Y_1 - y_1)x_2}{y_2 - y_1}$$

(44) If $Y_2 < y_1$ and $Y_2 < y_2$,
recycle to (3)

(45) If $y_1 < Y_2 < y_2$,

$$y_2 \rightarrow Y_2$$

$$x_2 \rightarrow \frac{(y_2 - Y_2)x_1 + (Y_2 - y_1)x_2}{y_2 - y_1}$$

(46) If $y_2 < Y_2 < y_1$,

$$y_1 \rightarrow Y_2$$

$$x_1 \rightarrow \frac{(y_2 - Y_2)x_1 + (Y_2 - y_1)x_2}{y_2 - y_1}$$

Plot Segment

(47) $p \rightarrow p - q$

(48) $q = \sqrt{(x_2 - x_1)^2 + \left(\frac{y_2 - y_1}{1.2}\right)^2}$

(49) Store $\frac{x_2 - x_1}{q}$

(50) Store $\frac{y_2 - y_1}{q}$

(51) Bypass to (67)

(52) $x \rightarrow x_1 + \frac{p}{q}(x_2 - x_1)$

(53) $y \rightarrow y_1 + \frac{p}{q}(y_2 - y_1)$

(54) $p \rightarrow p + \frac{1}{719.4}$

(55) If $F \neq 0$, bypass to (58)

(56) $\sigma \rightarrow 0$

(57) Renew F

(58) If $F \neq 0$, bypass to (62)

(59) $\sigma \rightarrow \sigma + 1$

(60) Shift F

(61) Recycle to (58)

(62) Decrement F

(63) If σ is odd, bypass to (67)

(64) $x \rightarrow 1199x$, rounded

(65) $y \rightarrow 1199y$, rounded

(66) Print dot at x, y

(67) If $p \leq q$, recycle to (52)

(68) If $p > q$, recycle to (3)

Library Code

Block 0134 in Deck 2500 contains the NORC code. Beginning of block words and assembly instructions are as follows:

Program	BOB	0991	1001	1243	0134
Guide Words	Block	0135			
Subroutines	Any computing program between locations S and R with R blank.				

Storage Allocation

Allowance for N consecutive CRT locations beginning with location 1244 to store map data.

Input

a. File of datum words in blocks of length N or less and with *EOF* on tape code xx.

b. The starting line S and the return line R of the conversion routine in the call lines.

c. The tape code xx, the camera selection σ , and the symbol selection β in the call lines.

d. The format word in location *F*.

e. The *X* map coordinate of the datum point in location *P* and the *Y* map coordinate of the datum point in location *P* + 1.

f. The map coordinate of the left edge of the printer field in location *H* and the map coordinate of the right edge of the printer field in location *H* + 1.

g. The map coordinate of the upper edge of the printer field in location *V* and the map coordinate of the lower edge of the printer field in location *V* + 1.

h. The map coordinate of the left edge of the rectangular area in location *X* and the map coordinate of the right edge of the rectangular area in location *X* + 1.

i. The map coordinate of the upper edge of the rectangular area in location *Y* and the map coordinate of the lower edge of the rectangular area in location *Y* + 1.

Output

a. The latitude in location *Q* and the longitude in location *Q* + 1.

b. Map on the CRT printer.

Call Lines	*L*	0060	*L*	-	1001
	L + 1	xx94	*H*	*V*	*F*
	L + 2	*R*	*S*	*P*	*Q*
	L + 3	σβ88	*X*	*Y*	*C*
Exit Line	The routine transfers control to *C*, or to *L* + 4 if *C* is blank.				

Program Stop

The routine stops on line 1189 for TCF if Sw 68 is on proceed. Full start after program stop reads in next block.

Limitations

a. The routine will only operate in 2K storage.

b. The routine uses modifiers but resets them to previous values prior to each transfer of control outside the routine. Addresses in the call lines cannot be modified. Printer counters are not reset.

c. Input data must be in degrees and minutes, or in minutes and seconds while output data are in degrees and decimal parts, or in minutes and decimal parts in NORC form. Map coordinates may be expressed in any set of consistent units.

d. The format word must not be completely blank.

Modification

a. The printer specifications of every dot which is plotted in the map may be retrieved for further use if the map plotting routine is modified to transfer control from location 1184 to a location *M*. Then the *X* specification will be found in location 1242 and the *Y*

specification will be found in location 1243. Finally the control must be returned to line 1185 in the map plotting routine. The modification is as follows:

Explanation	Line		Code		
Construction Word	1203	0000	1242	1243	*M*

Average Time

A representative time of operation is 34 millisecs per datum of input for the Mercator projection.

WORLD MAP

For a world map, the diameter of the plotting dot corresponds to 30′ of latitude and the unit distance in the CRT field corresponds to 15′ of latitude. The distance between datum points therefore has been made the same as the distance for 30′ of latitude, unless a smaller distance of not less than 15′ of latitude is necessary for character identification of the shore line. Latitudes and longitudes were recorded to the nearest 5′ of arc.

Coastal features which required special attention and the choices of polygon which have been made in their representation are as follows.

Inlets and Fjords The polygon crosses the mouth of each inlet from promontory to promontory.

Lagoons and Sand Bars The polygon runs along the inner edge of the sand bar.

Offshore Rocks The polygon runs through the midst of the rocks.

Salt Marshes The polygon marks the edge of open water.

Shelf Ice and Glacial Tongues The polygon follows the land under the ice.

The continuity of the data is interrupted at 180° longitude. In order to plot a map which straddles this longitude, the map is prepared in two sections. For the first section, zero is added to the longitude and the map is plotted to the west of the 180° meridian. For the second section, 360° is added to the longitude, whence the map is completed to the east of the 180° meridian.

A total of 8200 data are contained in the file for the world map. A Mercator map required 13 minutes for computation, but after the plot specifications had been saved on tape, the plot required only 17 seconds for duplication. The mapping data are catalogued in Appendix A and representative maps are presented in Appendix B. Figures 1 to 7 are cylindrical conformal projections while Figures 8 and 9 are polar conformal projections.

UNITED STATES MAP

For a United States map, the diameter of the plotting dot corresponds to about 5′ of latitude. The distance between datum points is equal to or less than the distance for 5′ of latitude, and the accuracy of recording is on the order of 1′ of arc. There are a total of 10,000 data in the file for the United States.

Included in the data are the major lakes in addition to the ocean shores, together with interstate and international boundaries. The mapping data are catalogued in Appendix A, and representative maps are presented in Appendix B. Figures 10 to 37 are conic conformal projections.

POTOMAC MAP

For a map of the Potomac River Area, from Washington, D. C. to Dahlgren, Virginia, coordinate positions in degrees and minutes would be too coarse. Each datum word therefore expresses in minutes and seconds the deviation of latitude from 38° 00′ 00″ N and the deviation of longitude from 77° 00′ 00″ W. In addition to data on the banks of the Potomac River there are included a few highway routes to Dahlgren. (Some of these routes may not be constructed until after release of this report.) There are a total of 5700 data in the file on the Potomac River Area. The data are catalogued in Appendix A and maps are presented in Appendix B. To derive Figure 40 from the data for Figures 38 and 39 required a massive amount of editing, even with the help of computing routines which doubled highways or suppressed segments.

DISCUSSION

Inspection of the sample maps shows that when data are used at drastically reduced scale any near confluence of lines causes a deleterious line thickening. The avoidance of such confluences is influenced by subjective evaluations of the relative importance of details to be eliminated. In the ultimate refinement of an irregular line, the length of segment would be equal to the diameter of dot, but the optimum polygonalization appears to have a length of segment several times larger than the diameter of the dot. Too fine a polygonalization loses meaning because of roundoff, and too coarse a polygonalization dominates the representation. An artful polygonalization can enhance the appearance of a map by accentuating the principal characteristics of boundary lines without deviating significantly from accuracy.

CONCLUSION

In a drastic reduction of scale the data for a map must be edited subjectively to remove deleterious detail.

REFERENCES

1. *Elements of Map Projection,* C. H. Deetz and O. S. Adams, U. S. Dept. of Commerce, Special Publication No. 68 (U. S. Government Printing Office, Washington, D. C. 1945).

2. *Universal Transverse Mercator Grid,* Army Map Service Technical Manual No. 19. (Army Map Service, Washington, D. C. Dec. 1955)

3. *American Practical Navigator,* N. Bowditch (U. S. Navy Hydrographic Office, Washington, D. C. 1938)

4. *The World* (U. S. Navy Hydrographic Office, Washington, D. C. May 1955)

5. *Antarctica.* (National Geographic Society, Washington, D. C. Sept. 1957)

6. *The Top of the World.* (National Geographic Society, Washington, D. C. Oct. 1949)

7. *World Aeronautical Charts.* (U. S. Coast and Geodetic Survey, Washington, D. C. 1959)

8. *Washington.* (U. S. Geological Survey, Washington, D. C. 1961) Map No NJ 18-4

9. *Suburban and Central Washington.* (National Geographic Society, Washington, D. C. 1948)

10. *Potomac River.* (U. S. Coast and Geodetic Survey, 1962) Small-craft Chart Series - 101

11. *Dahlgren and Vicinity.* (U. S. Coast and Geodetic Survey, 1959) Map No. 556

12. *Index Map* (U. S. Naval Weapons Laboratory)

13. *Dulles International Airport.* (U. S. Coast and Geodetic Survey)

14. County Maps, Oil Company Maps, and informal surveys with compass and odometer.

APPENDIX A

DATA

CATALOG OF MAP DATA

Deck 2520

WORLD MAP

Block Number	Coast Line
0010 to 0070	ANTARCTICA
0080	Ross Island, Roosevelt Island, Guest Island.
0090	Alexander Island, Charcot Island, Palmer Archipelago, Joinville Island.
0100	Drygalski Island, Bowman Island, Young Island, Sturge Island, Peter I Island, King George Island, Elephant Island, Clarence Island, Coronation Island, Laurie Island.
1010 to 1150	WESTERN CONTINENT
1160	Great Bear Lake, Great Slave Lake, Lake Athabaska, Reindeer Lake.
1170	Lake Winnipeg.
1180	Lake Superior, Lake Michigan, Lake Huron.
1190	Lake Erie, Lake Ontario.
1200	Isla de Pascua, Isla Sala y Gomez, Isla Isabela, Isla Santa Cruz, Isla San Cristobal, Isla del Coco, Isla de Malpelo, Isla San Ambrosio, Mas Afuera, Mas a Tierra.

Block Number	Coast Line
1210	Isla de Chiloe, Tierra del Fuego, Falkland Islands.
1220	South Georgia, Zavodoski Island, Saunders Island, Thule Island, Ascension, St. Helena, Trinidade, Tristan Island, Gough Island, Bouvet Island.
1230	Trinidad, Bonaire, Curacao, Aruba, Jamaica, Isla de Pinos.
1240	Cuba, Hispaniola.
1250	Puerto Rico, St. Croix, Anegada, Sombrero, Anguilla, St. Kitts, Antigua, Guadaloupe, Dominica, Martinique, St. Lucia, St. Vincent, Grenada, Barbados, Tobago.
1260	Andros Island, Inagua, Grand Bahama, Great Abaco, Nassau, Eleuthera, Cat Island, San Salvador, Long Island, Crooked Island, Mayaguana, Caicos, Grand Turk, Bermuda, Key West, Cape Hatteras, Long Island.
1270	Anticosti Island, Prince Edward Island, Coats Island, Mansel Island, Belcher Islands, Akimiski Island.

Block Number	Coast Line
1280	Newfoundland, Southampton Island.
1290	Prince Charles Island, Baffin Island.
1300	Bylot Island, Cornwallis Island, Devon Island.
1310	Axel Heiberg Island, Ellesmere Island.
1320	Meighen Island, Ellef Ringnes Island, Amund Ringnes Island, Cornwall Island, Lougheed Island, Bathurst Island, Byam Martin Island, Prince of Wales Island.
1330	Borden Island, Brock Island, Mackenzie King Island, Eglinton Island, Prince Patrick Island, Melville Island.
1340	Victoria Island, Banks Island.
1350	Bering Island, Attu Island, Kiska Island, Tanaga Island, Adak Island, Atka Island, Seguam Island, Umnak Island, Unalaska Island.
1360	St. Lawrence Island, Nunivak Island, Kodiak Island, Queen Charlotte Islands, Vancouver Island.

Block Number	Coast Line
1370 to 1380	GREENLAND
1390	Iceland, Jan Mayen Island, Shannon Island.
2010 to 2210	EASTERN CONTINENT
2220	Lake Chad, Lake Victoria, Lake Tanganyika, Lake Nyasa.
2230	Black Sea, Azovskoe More.
2240	Caspian Sea.
2250	Aralskoe More, Ozero Balkhash, Ozero Baikal.
2260	Lake Ladoga, Lake Onega.
2270	Madagascar.
2280	La Reunion, Mauritius, Prince Edward Islands, Crozet, Mahe, Chago, Male, Socotra, Zanzibar, Iles de Kerguelen, Heard Island, Ile St. Paul, Ile Amsterdam, Andaman Islands, Little Andaman, Nicobar, Simeulue, Nias, Siberut, Enggano, Christmas Island.
2290	Ceylon, Hainan, Formosa.
2300	Kyushu, Shikoku, Honshu.
2310	Hokkaido.

Block Number	Coast Line
2320	Yaeyama, Miyako, Okinawa, Amami, Yaku, Hachijo, Aoga, Tori, Chichi, Haha, Iwo, Kunashiri, Etorofu, Uruppu, Shimushiru, Matsuwa, Onnekotan, Paramushiru, Ostrova Shantarski, Ostrov Karaginski.
2330	Sakhalin.
2340	Wrangel Island, Bolshoi Lyakhovskie, Maly Lyakhovskie, Novaya Ostrov, Ostrov Kotelny, Ostrov Bolshevik, Ostrov Komsomolets.
2350	Novaya Zemlya, Ostrov Kolguev.
2360	Franz Josef Land, Spitzbergen.
2370	Faeroe Islands, Shetland Islands, Orkney Islands, Hebrides, Fyn, Sjaelland, Falster, Lolland, Bornholm, Gotland, Ahvenanmaa, Saaremaa, Hiiumaa.
2380	Britain.
2390	Ireland.
2400	Corsica, Sardinia, Sicily, Peloponnesus, Crete, Cyprus.
2410	Iviza, Majorca, Minorca, Elba, Pantelleria, Malta, Carpathia, Rhodes, Cephalonia, Zante, Milos, Thira, Naxos, Tinos, Limnos, Lesvos, Chios, Samos.

Block Number	Coast Line
2420	Flores, Fayal, Terceria, Sao Miguel, Madeira, La Palma, Tenerife, Gran Canaria, Fuerteventura, Santo Antao, Boa Vista, Sao Tiago, Sao Tome, Fernando Poo.
3010 to 3030	AUSTRALIA
3040	Melville Island, Kangaroo Island, Tasmania.
3050 to 3060	New Zealand.
3070	Sumatra.
3080	Java, Bali.
3090	Lombok, Sumbawa, Flores, Alor, Wetar.
3100	Sumba, Timor, Jamdena Islands, Aru Islands.
3110	Great Natuna Islands, Bangka, Billiton, Madura.
3120	Borneo.
3130	Celebes.
3140	Halmahera, Buru, Ceram.
3150	Sula Islands, Obi Islands, Misoöl, Waigeo, Biak.
3160 to 3170	New Guinea.

Block Number	Coast Line
3180	Luzon.
3190	Palawan, Sulu, Mindoro, Samar, Panay.
3200	Mindanao.
3210	New Britain, Admiralty Islands, New Ireland, Bougainville, Choiseul, Vella Lavella, New Georgia, Santa Isabel, Malaita, Guadalcanal, San Cristobal.
3220	Santa Cruz Islands, Espiritu Santo, Malekula, Efate, New Caledonia, Lifu, Mare, Norfolk Island, Lord Howe Island, Chatham Islands, Auckland Islands, Antipodes Islands, Campbell Island, Macquarie Island.
3230	Ascuncion, Agrihan, Alamagan, Anatahan, Saipan, Tinian, Rota, Guam, Tobi, Merir, Sonsorol, Angaur, Peleliu, Babelthuap, Yap, Ulithi, Truk, Ponape, Kusaie, Marcus, Wake, Eniwetok, Bikini, Kwajalein, Wotje, Majuro, Jaluit, Makin, Tarawa, Tabiteuea, Nauru, Ocean Island, Nanumea, Funafuti, Viti Levu, Vanua Levu.
3240	Howland Island, Baker Island, Enderbury Island, Canton Island, McKean Island, Gardner Island, Hull Island, Phoenix Island, Atafu, Nukunono, Fakaofo, Savaii, Upolu, Tutuila, Niue, Vavau, Malinoa, Tongatapu, Raoul, Aitutaki, Rarotonga, Mangaia.

Block Number	Coast Line
3250	Johnston Island, Palmyra Island, Washington Island, Fanning Island, Christmas Island, Jarvis Island, Malden Island, Starbuck Island, Tongareva, Rakahanga, Manihiki, Vostok Island, Flint Island, Caroline Island, Tahiti, Bora Bora, Tubuai, Rapa, Makatea, Rotoava, Takapoto, Nihiru, Mangareva, Pitairn Island, Henderson Island, Nuku Hiva, Hiva Oa.
3260	Midway Island, Lisianski Island, Laysan, Gardner Pinnacles, French Frigate Shoal, Necker Island, Nihoa, Niihau, Kauai, Oahu, Molokai, Lanai, Maui, Kahoolawe, Hawaii.

CATALOG OF MAP DATA

Deck 2521

UNITED STATES MAP

Block Number	Boundary
0010 to 0070	WEST COAST
0080	Lopez Island, San Juan Island.
0090	San Miguel Island, Santa Rosa Island, Santa Cruz Island, San Nicolas Island, Santa Catalina Island, San Clemente Island.
0100	Columbia River.
0110	Colorado River.

Block Number	Boundary
0120	Lake Mead.
0130	Snake River.
0140	Lake Tahoe.
0150	Great Salt Lake.
0200 to 0220	Rio Grande.
0230 to 0240	Red River.
0250	Lake Texoma.
0260	Sabine River.
0270 to 0280	Missouri River.
0290	Sioux River.
0300	Red River of the North.
0310	St. Francis River, Des Moines River.
0320	Calcasieu Lake, Grand Lake, White Lake, Lake Maurepas.
0330	Lake Pontchartrain.
0400 to 0730	EAST COAST
0740	Padre Island, Galveston Island, Isles Dernieres, Timbalier Island.
0750	Grand Terre Island, Martin Island, Isle au Pitre, Chandeleur Islands, Cat Island, Ship Island, Horn Island, Petit Bois Island, Dauphin Island, Santa Rosa Island.
0760	Key West, Key Largo.

Block Number	Boundary
0770	Smith Island, Outer Banks, Hatteras Island, Roanoke Island, Hooper Island, Bloodsworth Island, South Marsh Island, Smith Island.
0780	Assateague Island, Fishers Island, Block Island, Conanicut Island, Prudence Island, Martha's Vineyard, Nantucket Island.
0790	Vinalhaven, Long Island, Isle au Haut, Swans Island, Great Wass Island, Head Harbor Island.
0800 to 0830	Mississippi River, St. Croix River.
0840	Pearl River, Perdido River, St. Mary's River.
0850	Chattahoochee River.
0860	Savanna River.
0870	Clark Hill Reservoir.
0880 to 0900	Ohio River.
0910	Wabash River.
0920	Tug Fork.
0930	Potomac River.
0940	Delaware River.
0950	Arthur Kill, Hudson River, East River.

Block Number	Boundary
0960	Lake Okeechobee.
1000 to 1010	Lake of the Woods.
1020	Rainy River.
1030	Rainy Lake.
1040 to 1080	LAKE SUPERIOR
1090	Madeline Island, Oak Island, Stockton Island, Outer Island, Isle Royale, Pie Island, Grand Island, Michipicoten Island.
1100	St. Mary's River.
1110 to 1200	LAKE MICHIGAN and LAKE HURON
1210	Washington Island, Manitou Island, Beaver Island, Bois Blanc Island, Cockburn Island, Fitzwilliam Island, Christian Island.
1220	St. Clair River, Lake St. Clair, Detroit River.
1230 to 1240	LAKE ERIE
1250	Niagara River.
1260 to 1270	LAKE ONTARIO
1280	Amherst Island, Wolfe Island, Thousand Islands.
1290	St. Lawrence River.
1300	St. John River.

Block Number	Boundary
1310 to 1320	St. Croix River.
1330	Menominee River.
1340 to 1350	Lake Champlain.
1360	Connecticut River.
1370	Salmon Falls River.
2000	United States-Mexico.
2010 to 2020	United States-Canada.
3000	California-Oregon, Utah-Idaho, Washington-Oregon, California-Nevada, Nevada-Utah, Oregon-Idaho, Washington-Idaho, Arizona-Utah, Oklahoma-Kansas, Utah-Wyoming.
3010 to 3020	Idaho-Montana.
3030	Idaho-Wyoming, Wyoming-Montana, Arizona-New Mexico, Utah-Colorado, New Mexico-Texas, New Mexico-Oklahoma, Colorado-Kansas, Wyoming-Nebraska, Montana-North Dakota, Kansas-Nebraska, Nebraska-South Dakota, South Dakota-North Dakota.
3040	Texas-Louisiana, Oklahoma-Arkansas, Kansas-Missouri, South Dakota-Minnesota, Louisiana-Arkansas, Arkansas-Missouri, Missouri-Iowa, Iowa-Minnesota.

Block Number	Boundary
3050	Louisiana-Mississippi, Florida-Alabama, Florida-Georgia, Mississippi-Alabama, Alabama-Georgia, Mississippi-Tennessee, South Carolina-North Carolina, Tennessee-Kentucky, North Carolina-Virginia.
3060	North Carolina-Tennessee.
3070	Virginia-Kentucky, Virginia-West Virginia.
3080	West Virginia-Maryland, Maryland-Virginia, Maryland-Pennsylvania, Maryland-Delaware, New Jersey-New York.
3090	Minnesota-Wisconsin, Illinois-Wisconsin, Wisconsin-Michigan, Illinois-Indiana, Indiana-Michigan, Indiana-Ohio, Ohio-Michigan, Ohio-Pennsylvania, Pennsylvania-New York, New York-Connecticut, Connecticut-Massachusetts, Massachusetts-New Hampshire, Connecticut-Rhode Island, New Hampshire-Maine.

CATALOG OF MAP DATA

Deck 2522

POTOMAC MAP

Block Number	Boundary
0010 to 0110	WEST BANK
0210 to 0320	EAST BANK
0410	Conn Island, Bealls Island, Clagett Island, Watkins Island, Van Deventer Channel.
0420	Columbia Channel, Waterfowl Sanctuary.
0430	Offut Island, Turkey Island, Theodore Roosevelt Island, Kingman Island, Goose Island.
0440	Cobb Island, St. Margaret Island, St. Catherine Island, Blakiston Island, Hollis Marsh.
1000	District of Columbia Line.
1010	US Route 1.
1020 to 1030	US Route 301.
1040	VA 2, VA 207.
1050	US Route 17.
1060 to 1070	VA Route 3.
1080	VA 205, VA 206.
1090	MD Route 210.

Block Number	Boundary
1100	Marshalls Corner Road, Bumpy Oak Road, MD 224, MD 225, MD 227, MD 414.
1110	VA 236, VA 7.
1120	Glebe Road.
1130	Mount Vernon Highway.
1140	Memorial Parkway.
1150	Washington Parkway.
1160	Jones Point Interchange.
1170	Davis Highway.
1180	Garfield Interchange.
1190	Shirley Highway, VA 350.
1200	Columbia Pike.
1210	US 29, US 50, US 211.
1220	Arlington Boulevard, Washington Boulevard.
1230	Fairfax Drive.
1240	Lee Highway, Spout Run Parkway.
1250	Dulles Airport Road.
1260	VA 123, VA 193.
1270	Canal Road, MacArthur Boulevard.
1280	MD 190, MD 187.
1290	Pooks Hill Interchange.

Block Number	Boundary
1300	Interstate 270, Interstate 70S, US 240.
1310	MD Route 355.
1320	Georgia Avenue, MD 97, MD 586, MD 182.
1330	MD Route 5.
1340	Suitland Parkway.
1350	MD Route 4.
1360	MD 214, MD 704.
1370	MD 202, MD 450.
1380	Fox Ferry Point Interchange.
1390	Anacostia Freeway, Interstate 295.
1400	Kenilworth Interchange.
1410	Kenilworth Avenue, MD 201.
1420	US Route 50.
1430	Baltimore Washington Parkway.
1440	US 1 Alternate, US 1.
1450	MD Route 650.
1460	US Route 29.
1470	MD Route 410.
1480	University Boulevard, MD 193.
1490 to 1500	Capital Beltway, Interstate 495.

Block Number	Boundary
1610	Franklin Street, Powhatan Street, Maine Avenue, M Street, Southwest Freeway, G Street, E Street, C Street (S), Independence Avenue.
1620	East Capitol Street, Constitution Avenue, C Street (N), F Street, K Street, M Street, U Street, Florida Avenue.
1630	Columbia Road, Harvard Street, Irving Street, Michigan Aven ue, Queens Chapel Road, MD 500, Military Road, Missouri Avenue.
1640	Eleventh Street, Sixth Street, Fourth Street, Second Street, First Street (E), South Capitol Street, Canal Street, Louisiana Avenue, North Capitol Street.
1650	First Street (W), Third Street, Sixth Street, Seventh Street, Twelfth Street, Thirteenth Street, Fourteenth Street, Fifteenth Street, Sixteenth Street, Alaska Avenue, Seventeenth Street, Twenty-second Street, Twenty-Third Street.
1660	Rock Creek Parkway.
1670	Virginia Avenue, Branch Avenue, Pennsylvania Avenue.
1680	Massachusetts Avenue.
1690	Wisconsin Avenue.

Block Number	Boundary
1700	Connecticut Avenue.
1710	North Carolina Avenue, Maryland Avenue, Benning Road, Bladensburg Road.
1720	New York Avenue.
1730	Rhode Island Avenue.
1740	Vermont Avenue, New Hampshire Avenue.
1750	Rochambeau Bridge, Mason Bridge, Memorial Bridge, Key Bridge, Chain Bridge.
1760	Seven Corners Circle, Memorial Circle, Lincoln Square.
1770	Washington Circle, Mt. Vernon Square, Scott Circle, Dupont Circle, Logan Circle, Ward Circle, Westmoreland Circle, Chevy Chase Circle, Grant Circle.
1810	Dulles International Airport, Washington National Airport, Andrews Air Force Base.
1820	US Capitol, White House.
1830	Lincoln Memorial, Washington Monument, Jefferson Memorial.
1840	Pentagon, Union Station.

Block Number	Boundary
2000	NWL Fence Line.
2010	Rosedale Drive, Potomac Drive, Gordon Drive, Williams Creek Drive, Ferry Dock Drive, Eleventh Street, Twelfth Street, Thirteenth Street, Fourteenth Street, Fifteenth Street, Forrest Road.
2020	Dahlgren Road, Gilmore Road, Hall Road, Sampson Road, Jenkins Road, Welsh Road, Greenslade Road.
2030	Jones Road, Alger Road, Earle Road, Caffee Road.
2040	First Street, Second Street, Third Street, Fourth Street, Avenue A, Avenue B, Avenue C, Avenue D.
2050	Bronson Road, Marple Road, McVay Road, Tisdale Road, Caskey Road.
2080	Airstrips.
2100	Cooling Pond.

APPENDIX B

MAPS

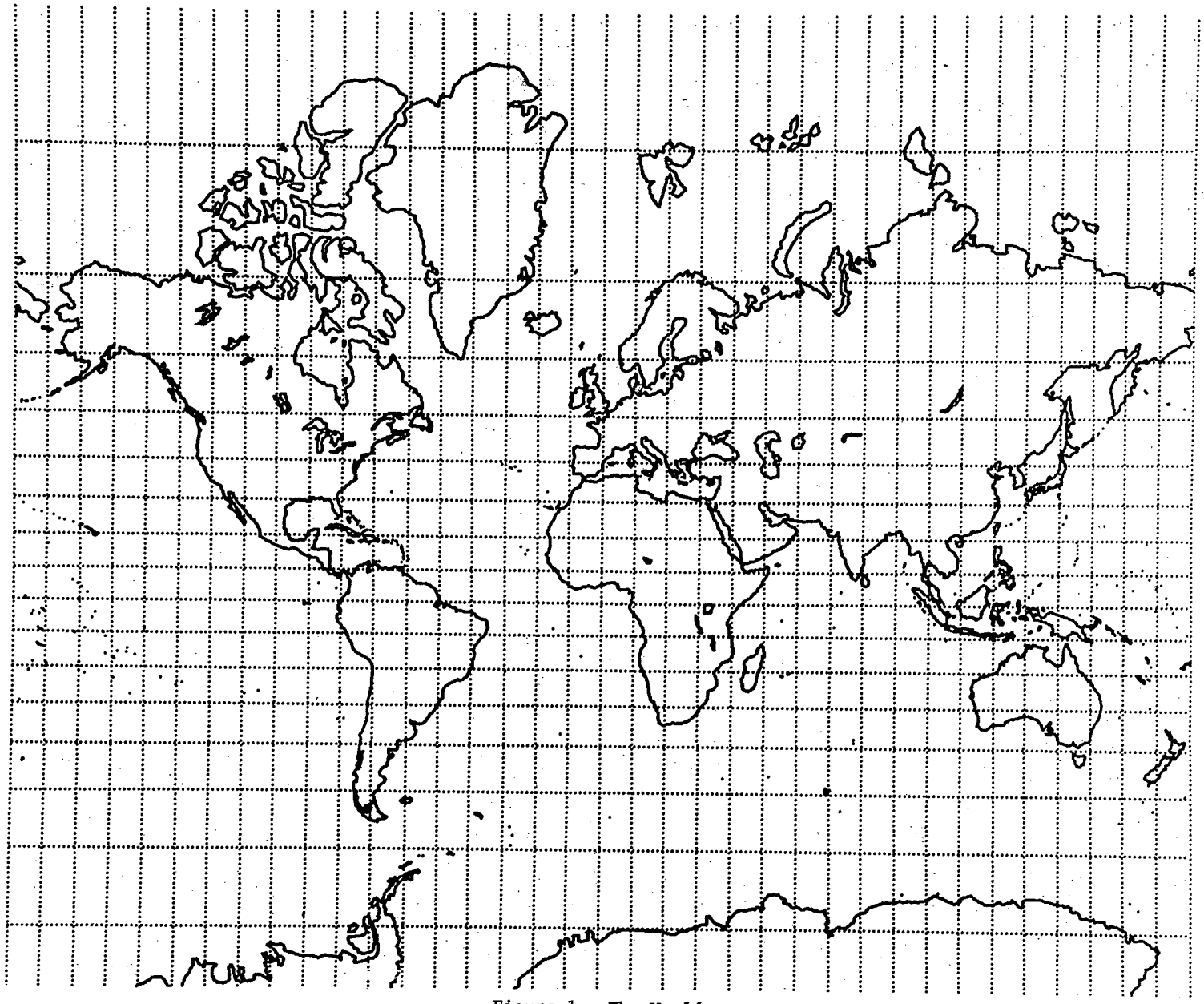


Figure 1. The World.

Figure 2. South America.

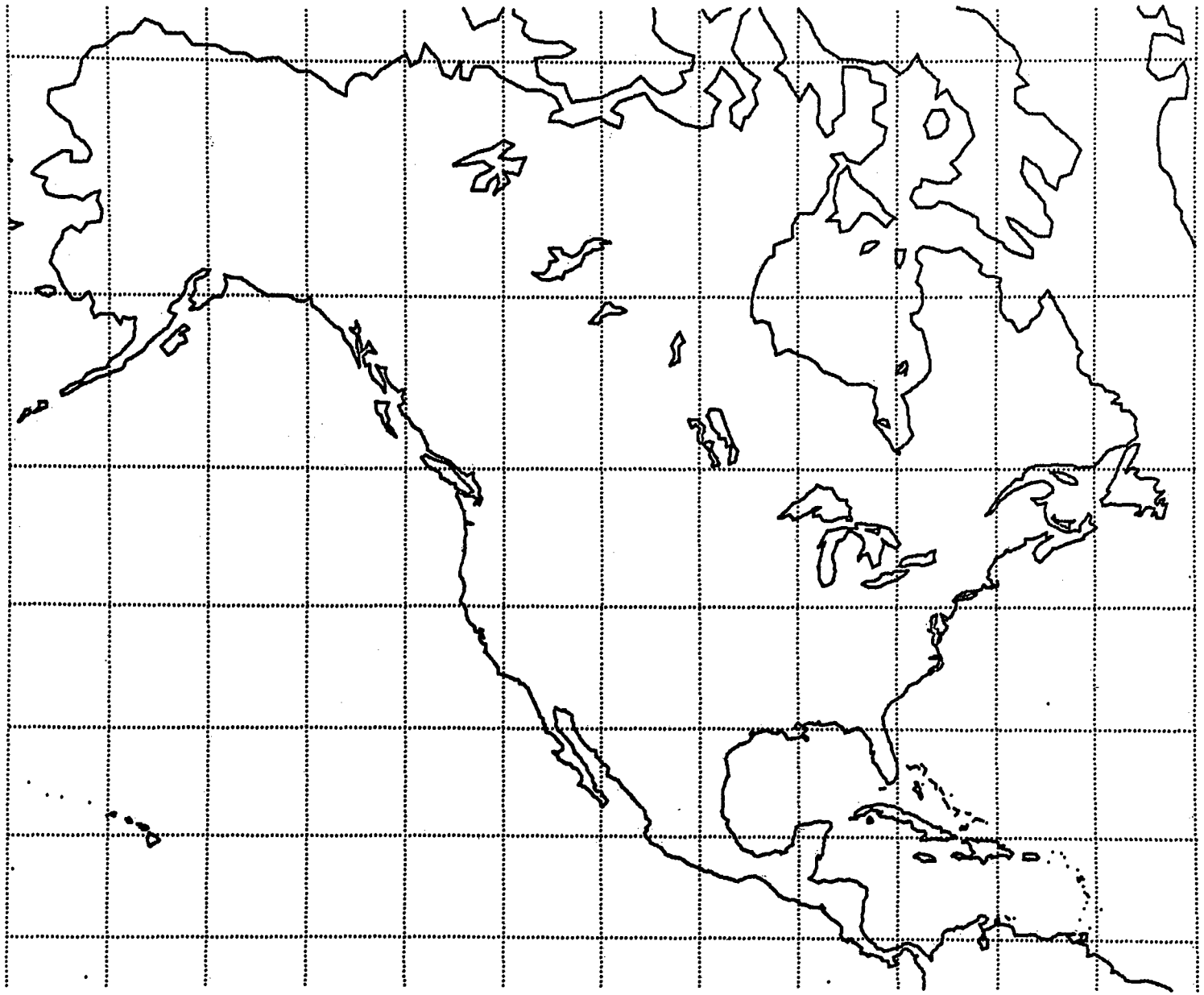


Figure 3. North America.

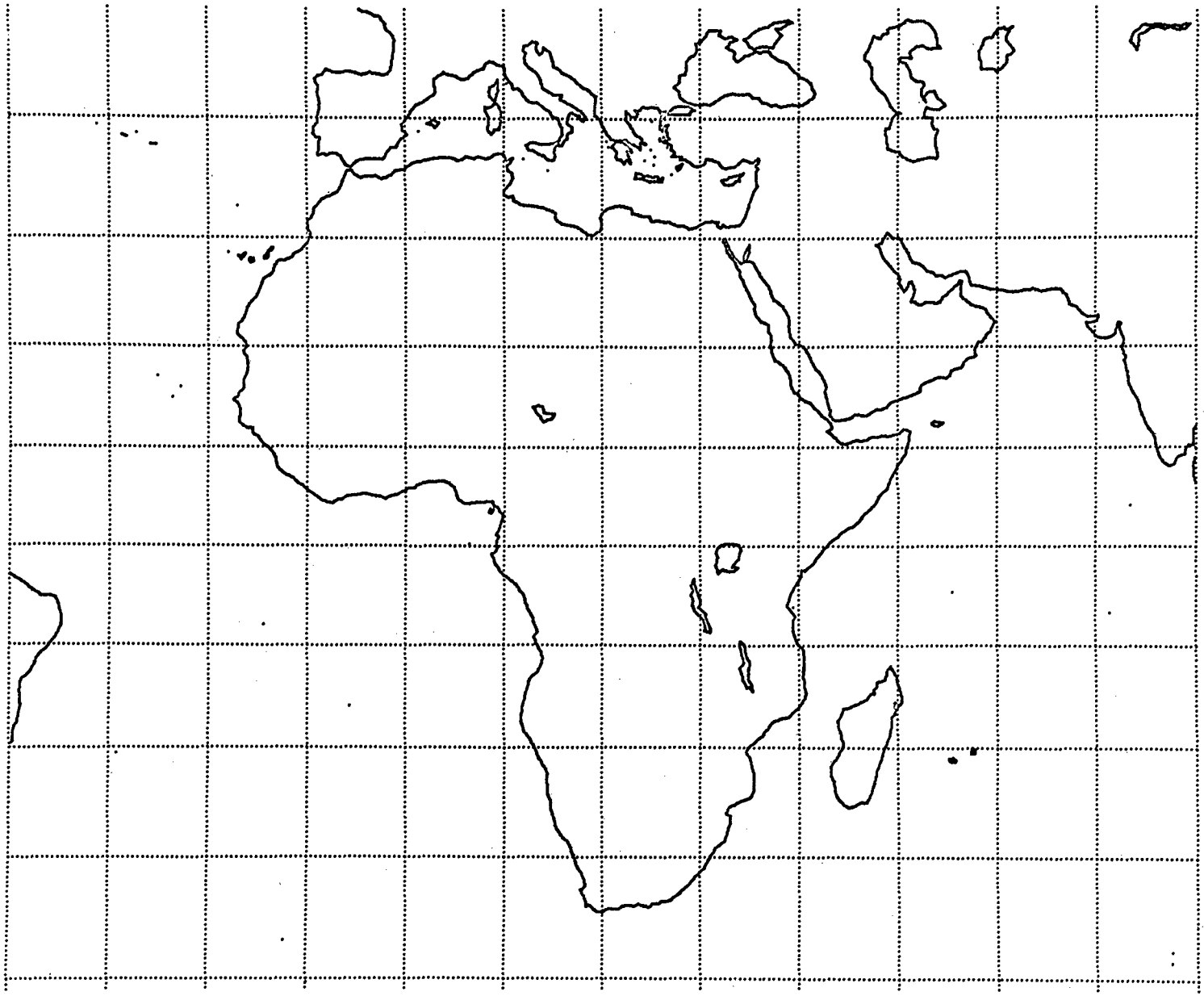


Figure 4. Africa.

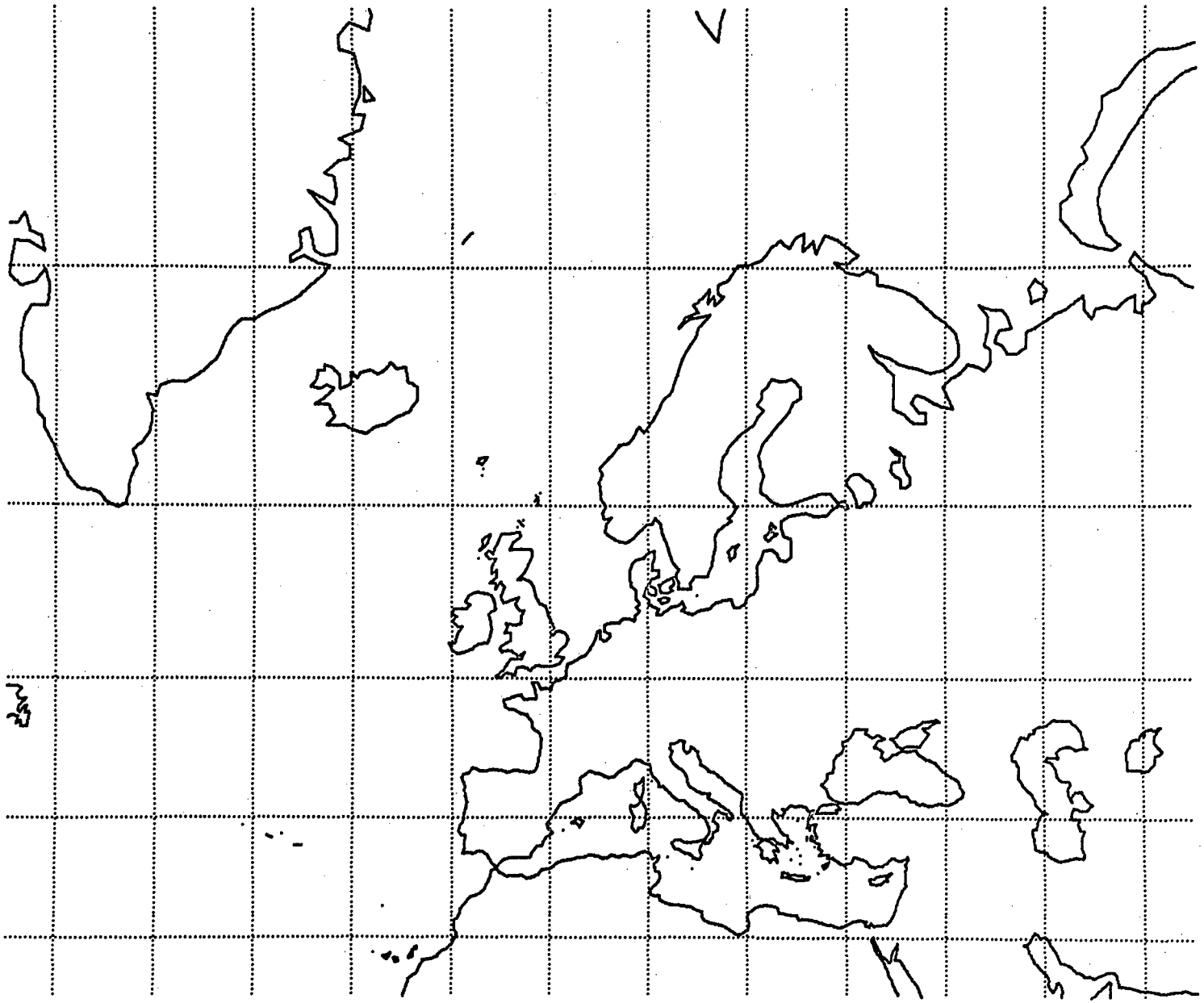


Figure 5. Europe

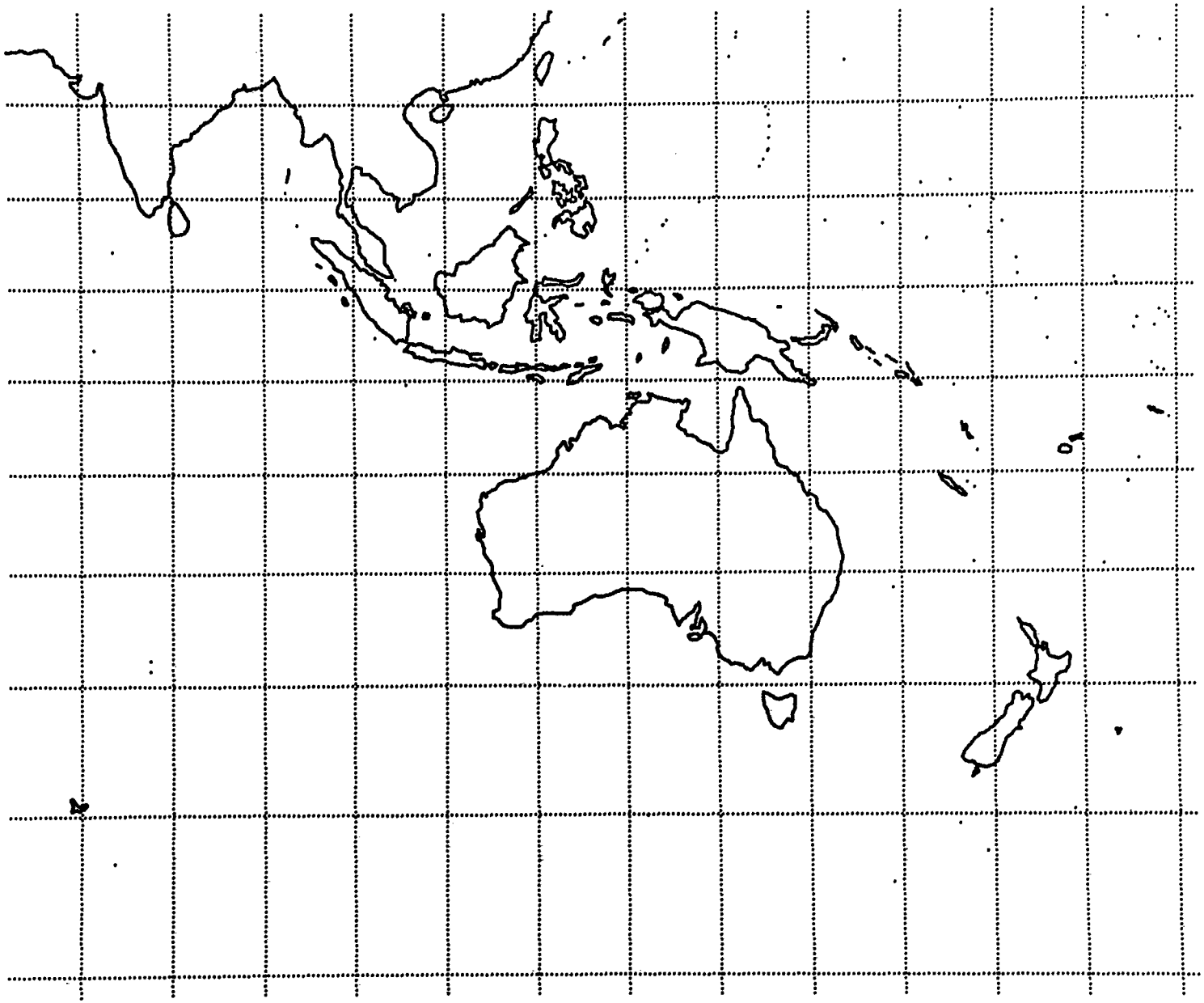


Figure 6. Australia.

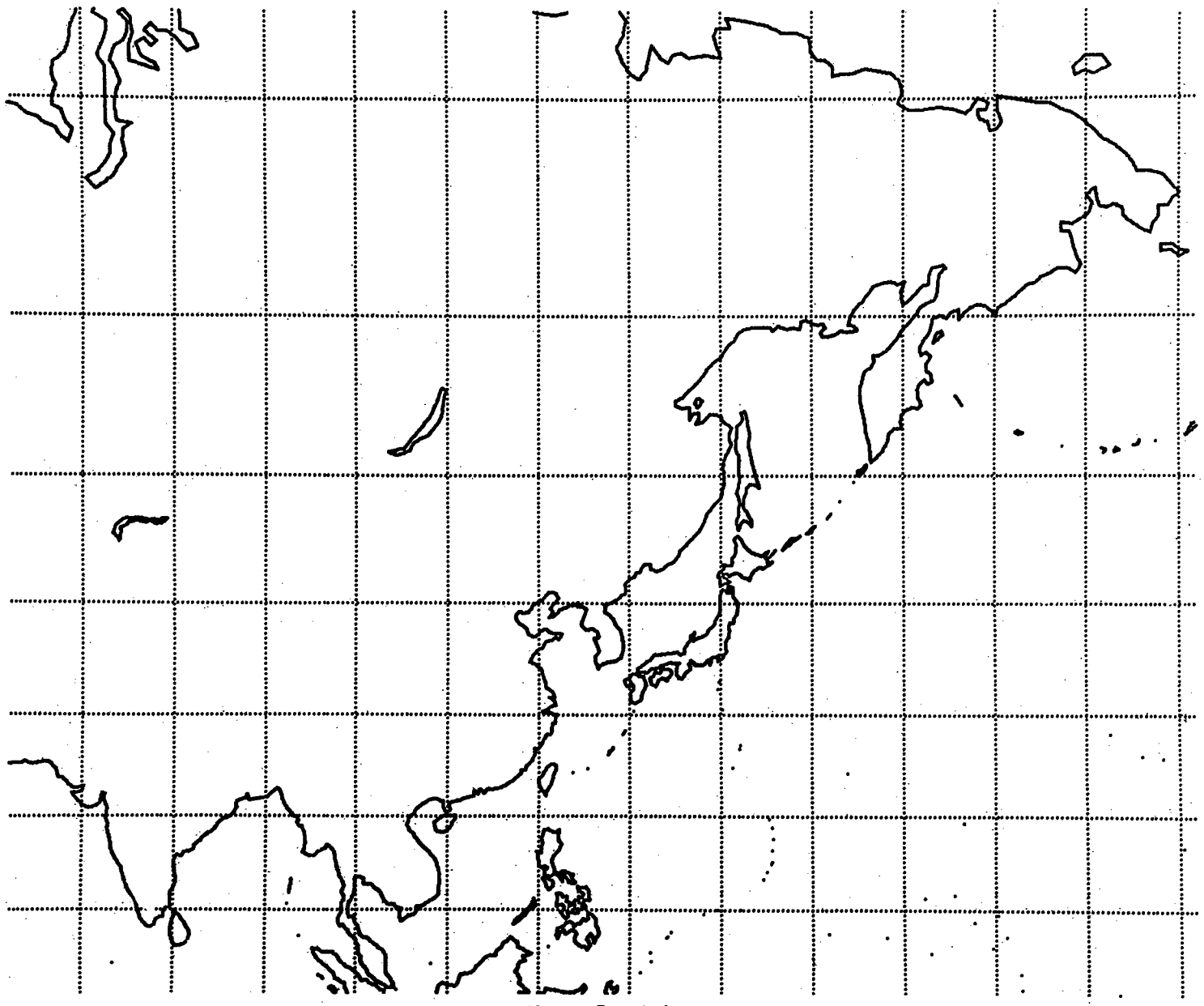


Figure 7. Asia.

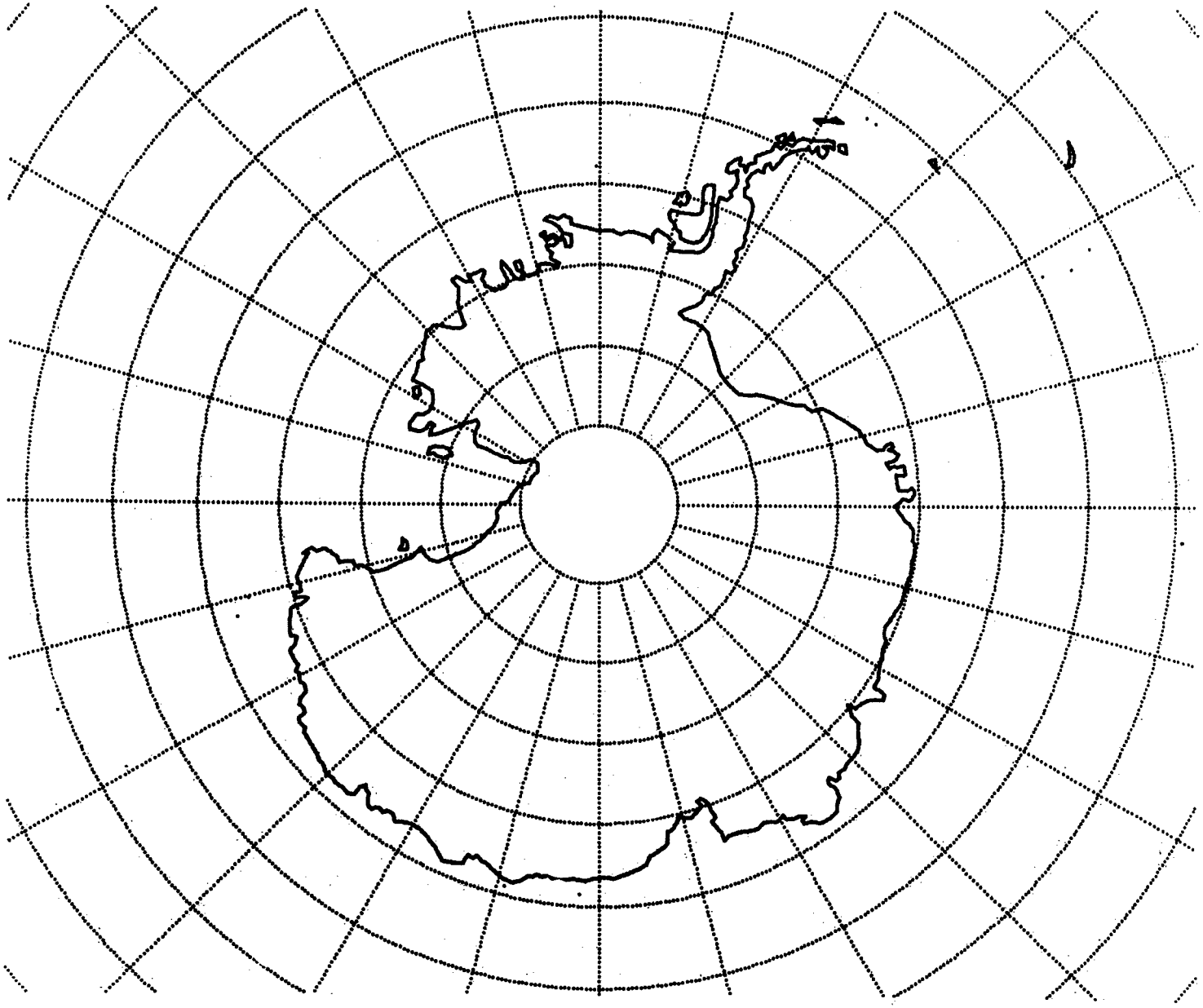


Figure 8. Antarctica.

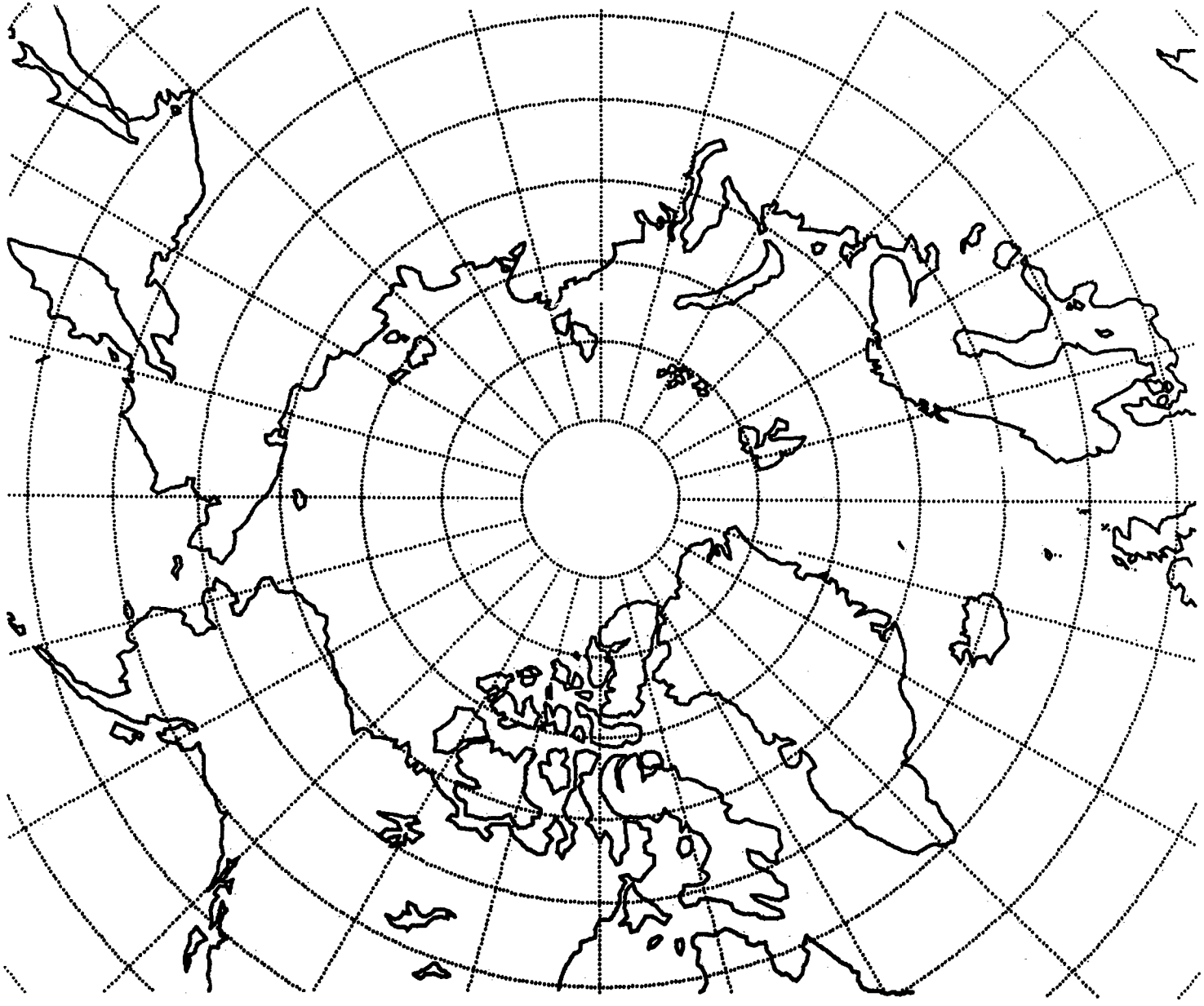


Figure 9. Arctic Ocean.

Figure 10. The United States.

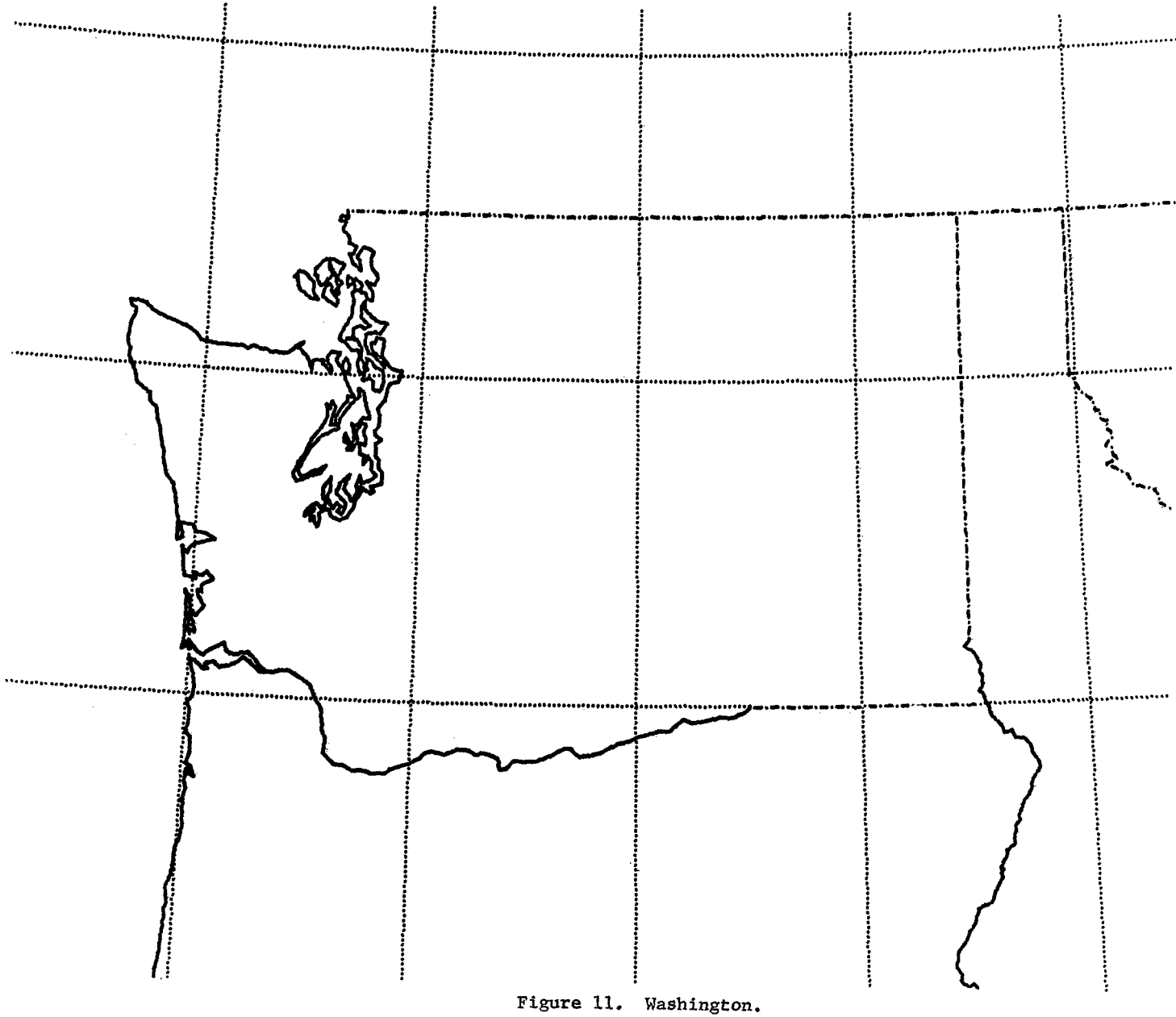


Figure 11. Washington.

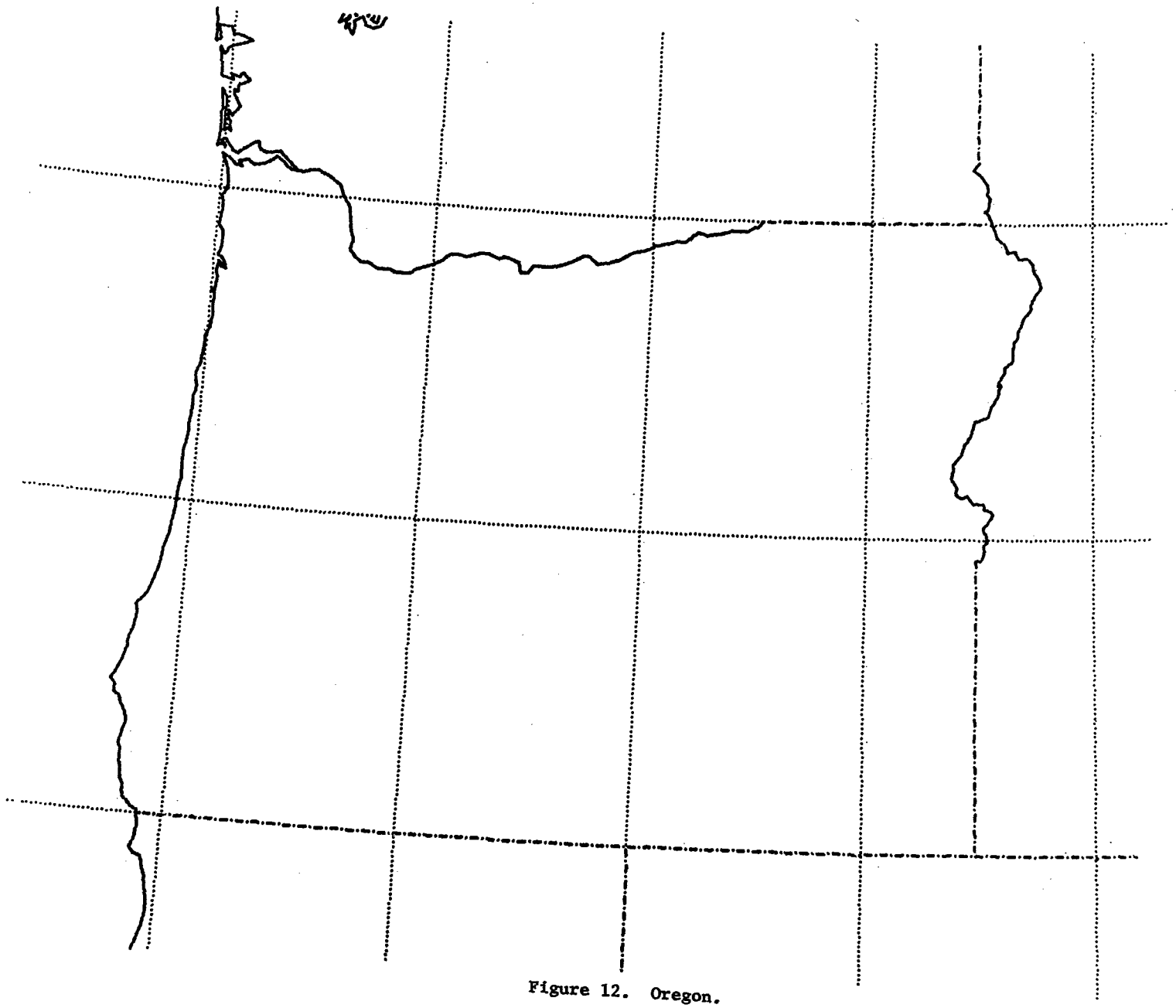


Figure 12. Oregon.

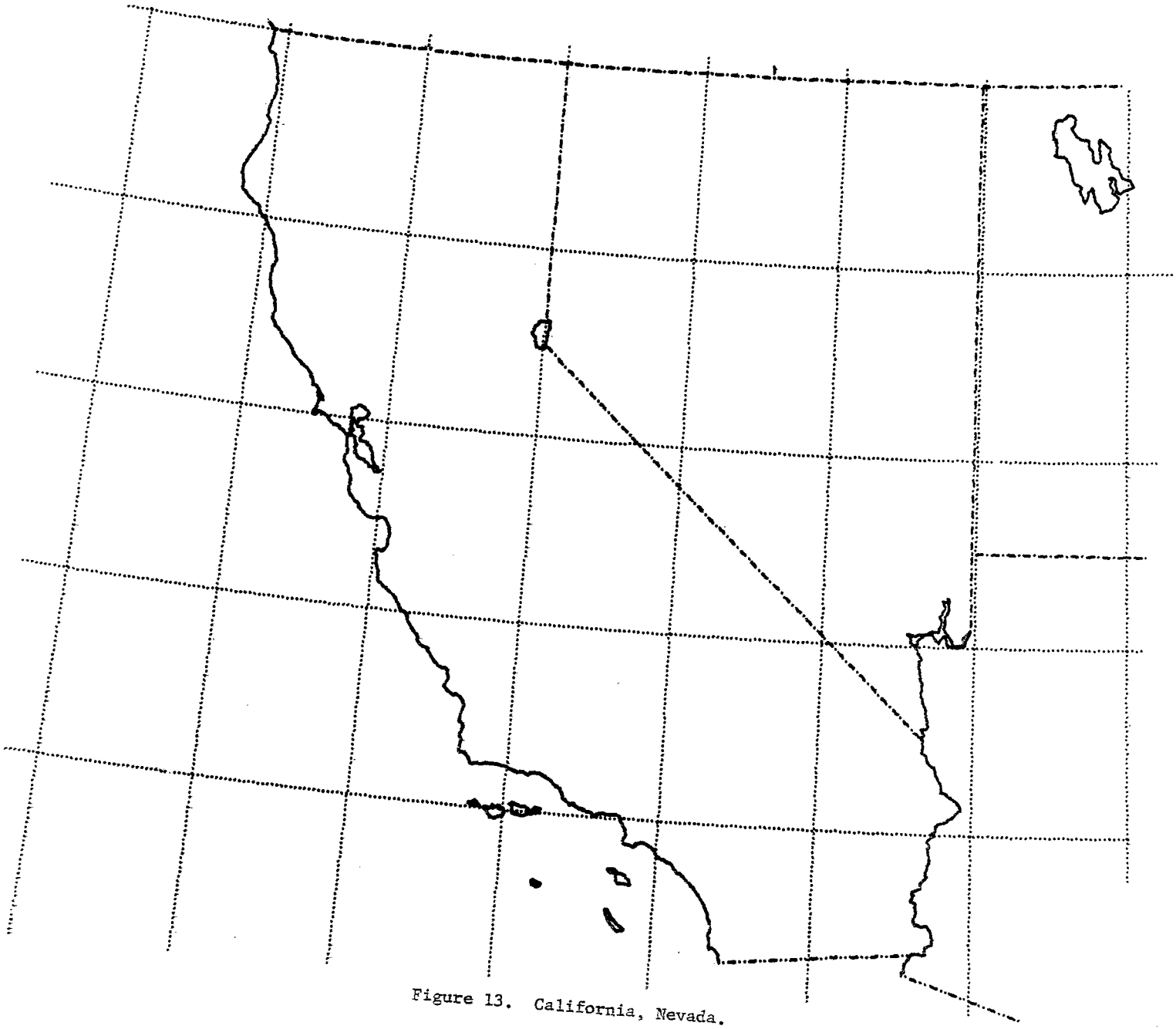


Figure 13. California, Nevada.

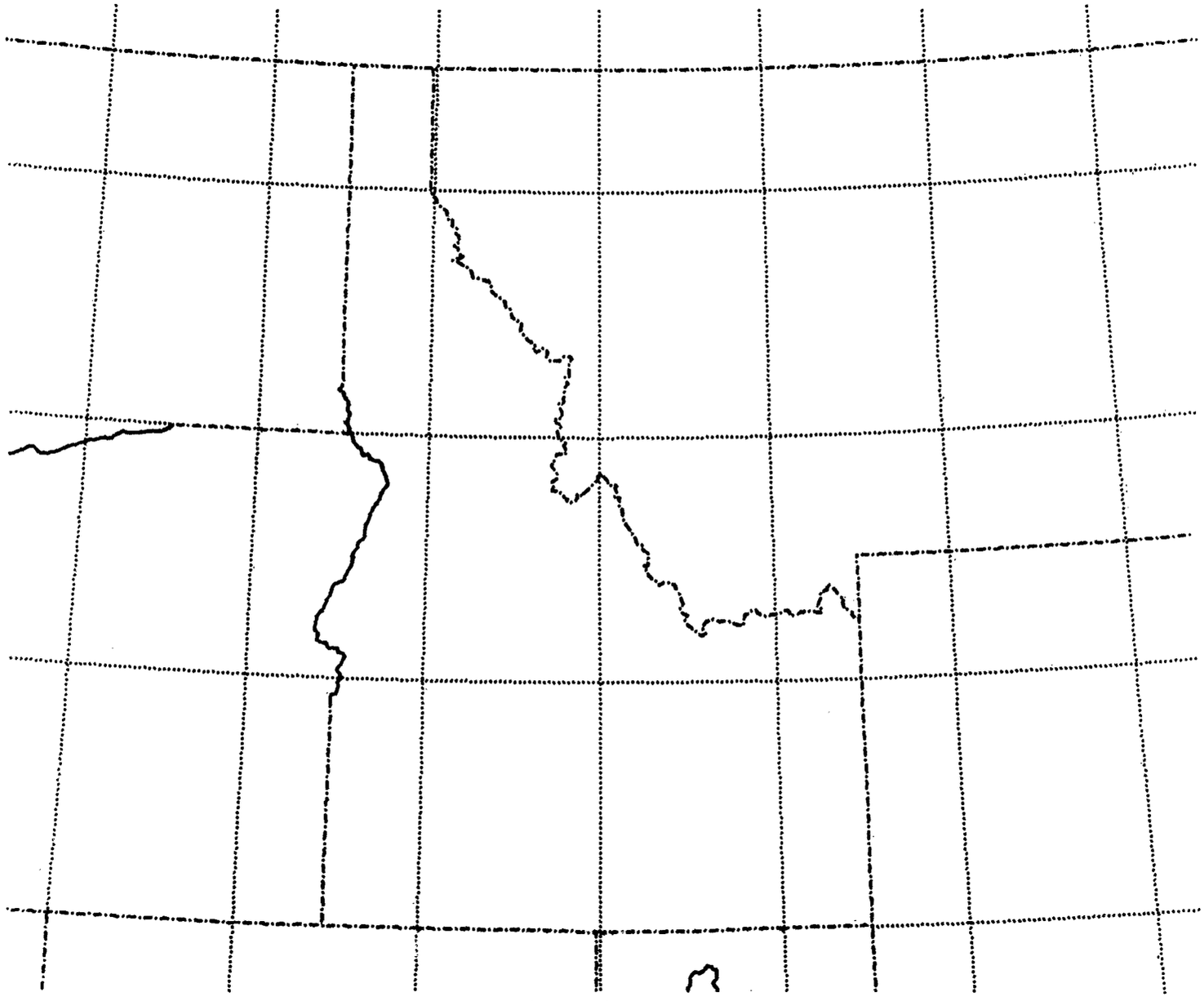


Figure 14. Idaho.

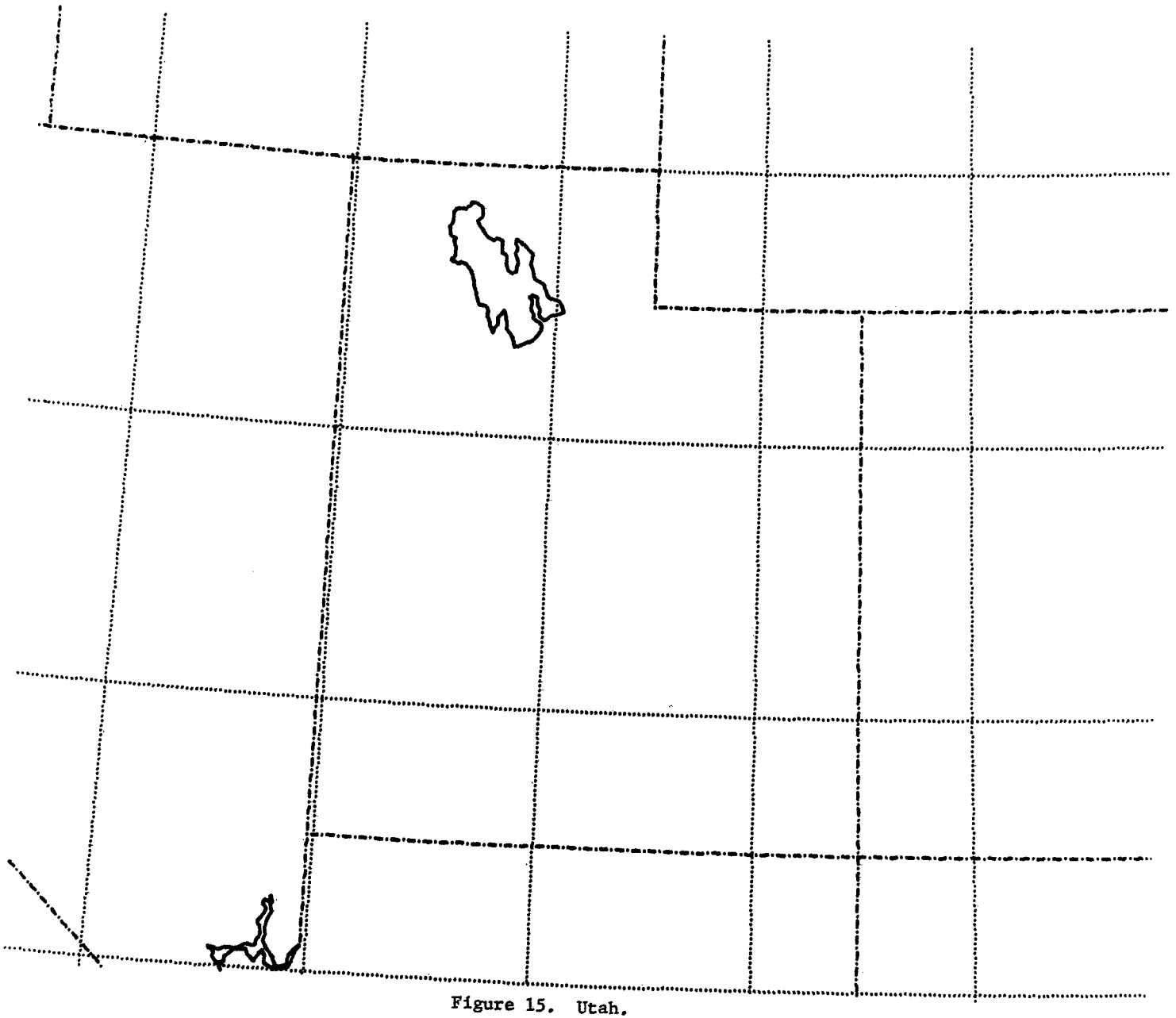


Figure 15. Utah.

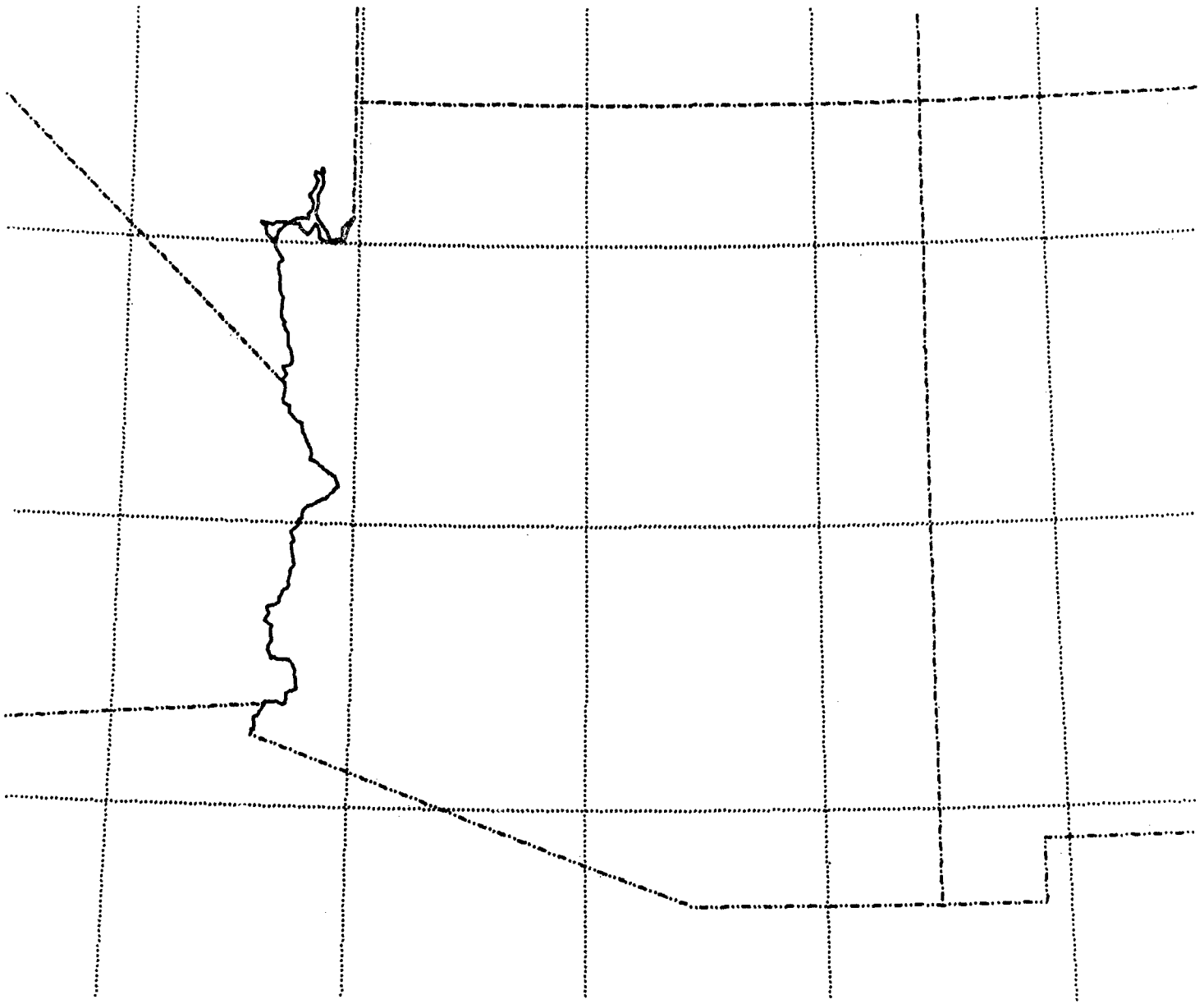


Figure 16. Arizona.

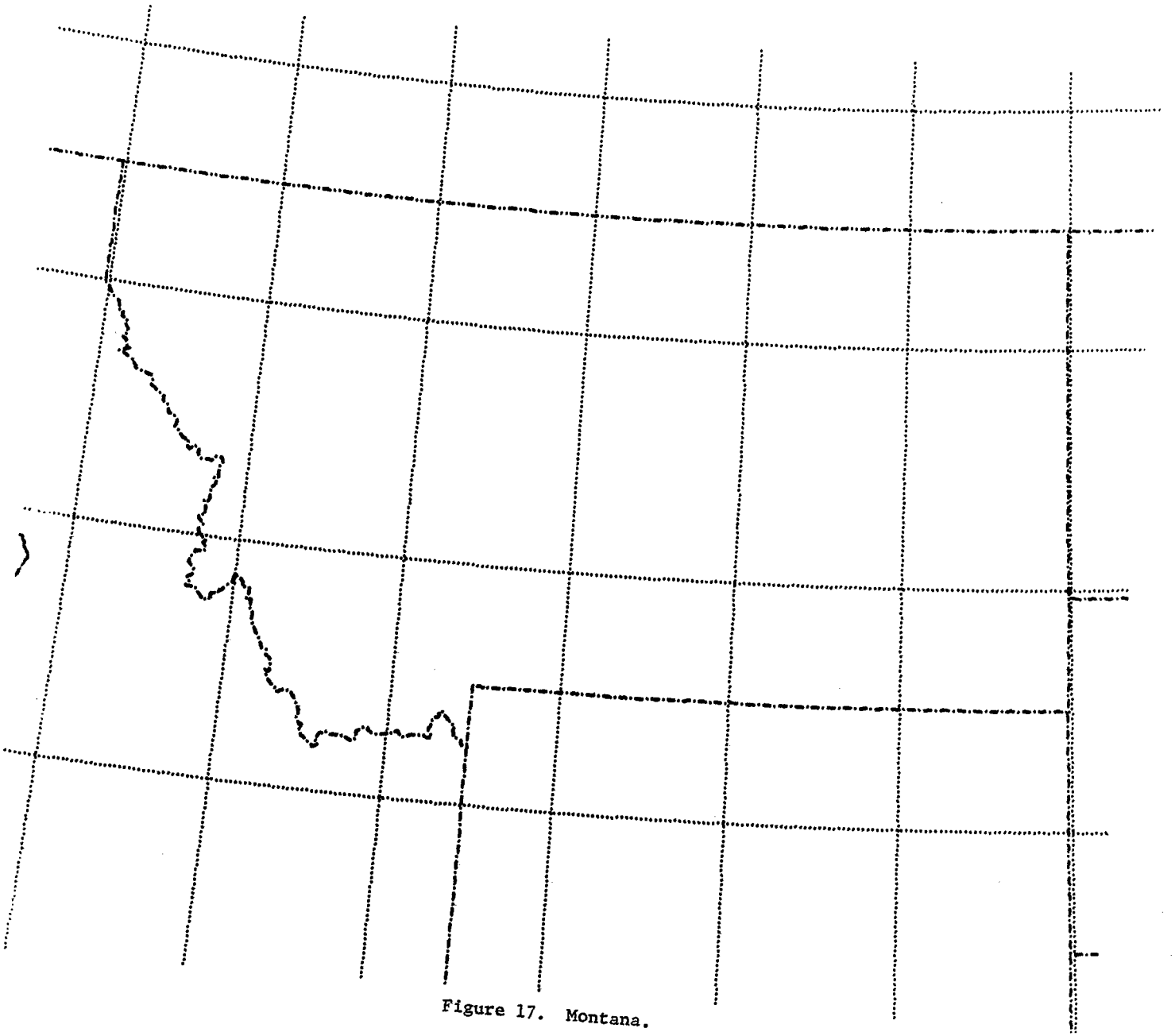


Figure 17. Montana.

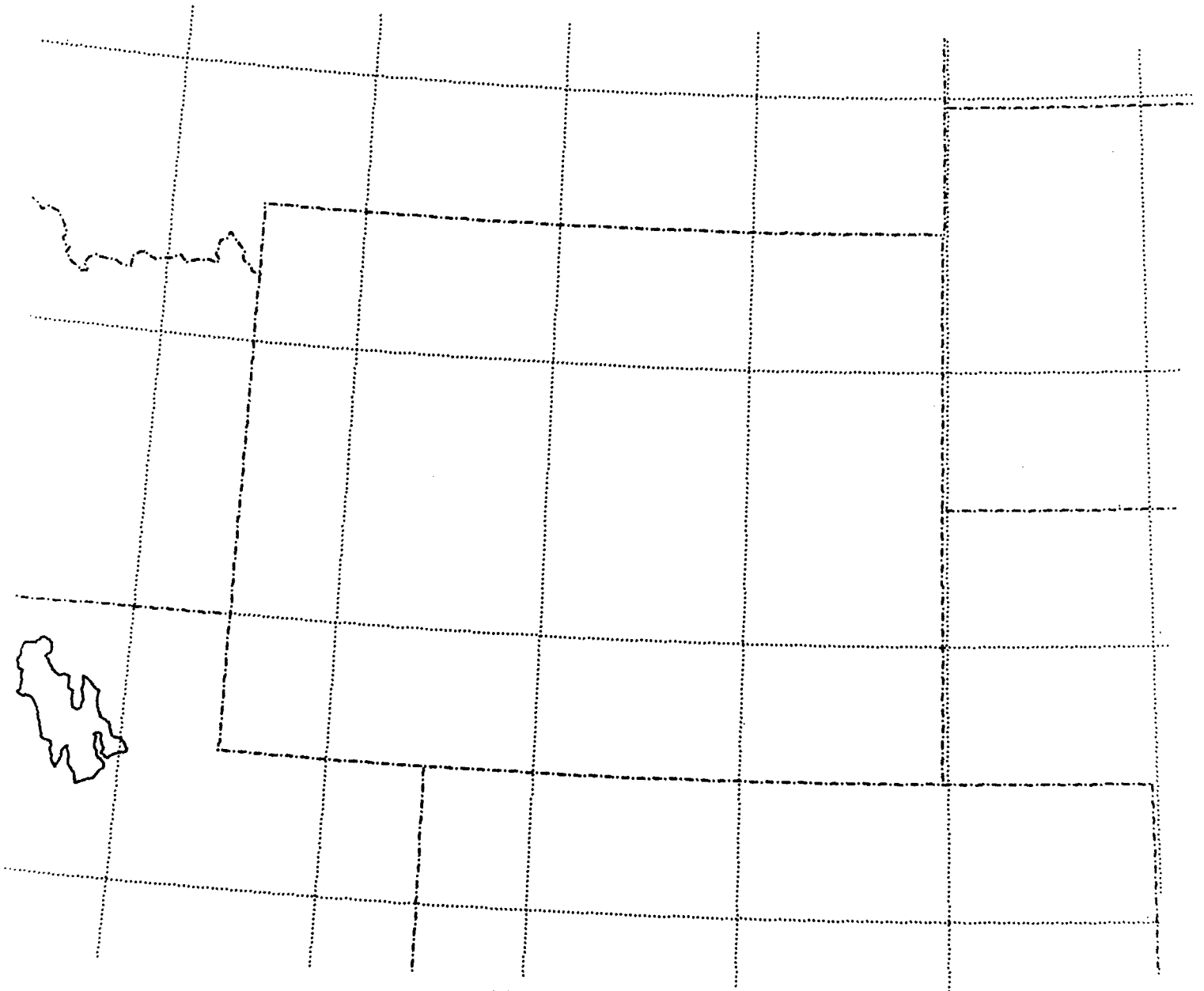


Figure 18. Wyoming.

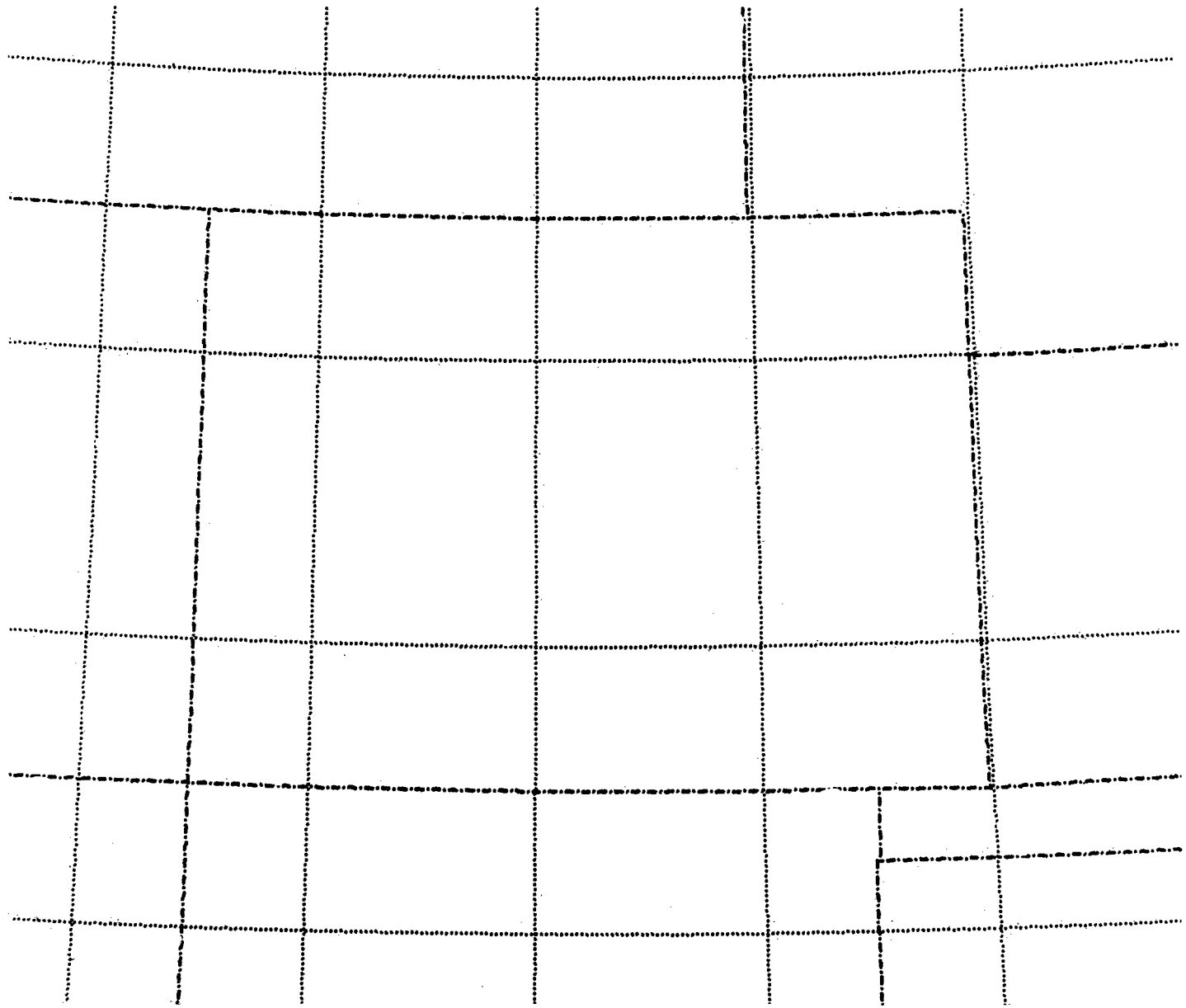


Figure 19. Colorado.

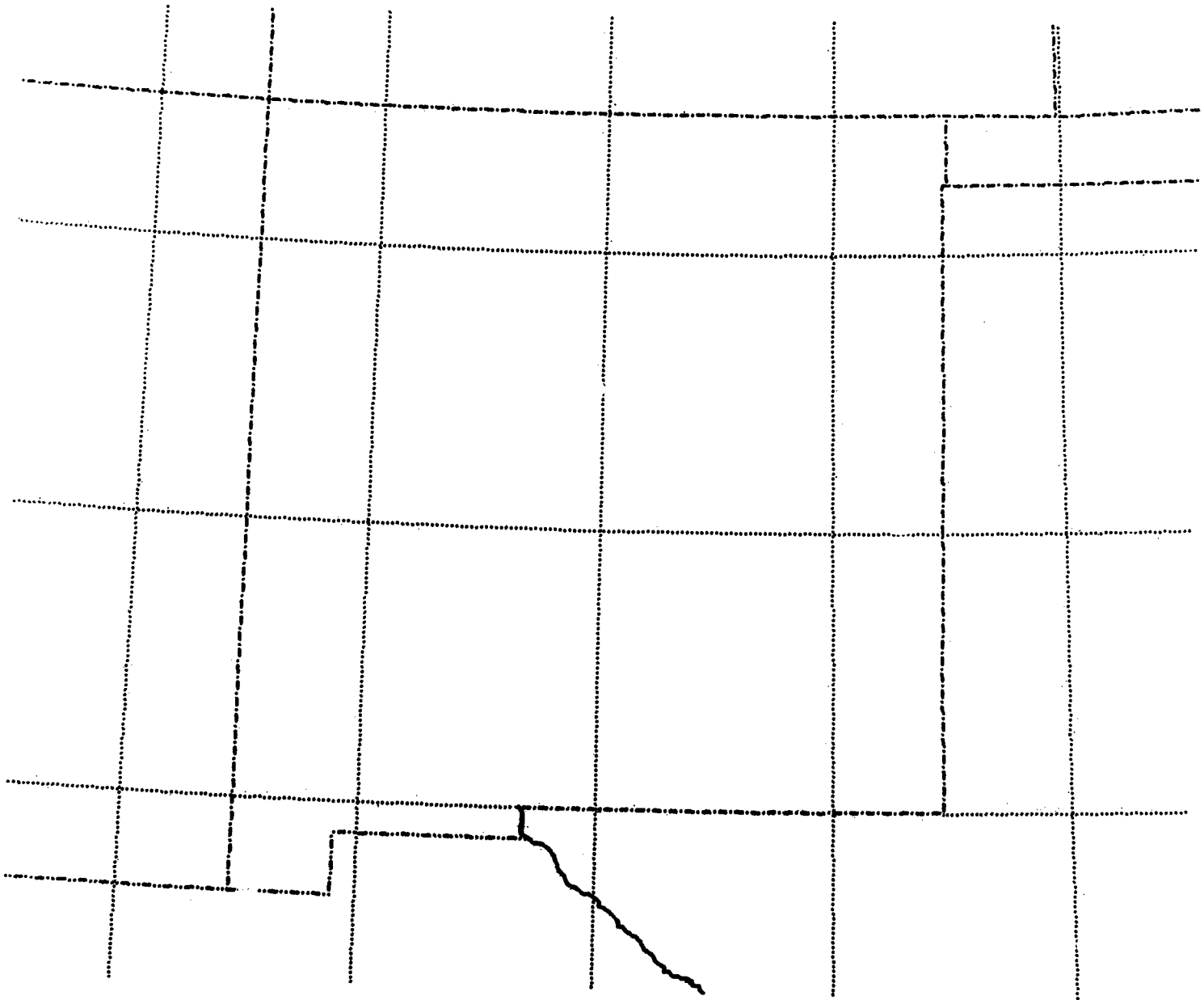


Figure 20. New Mexico.

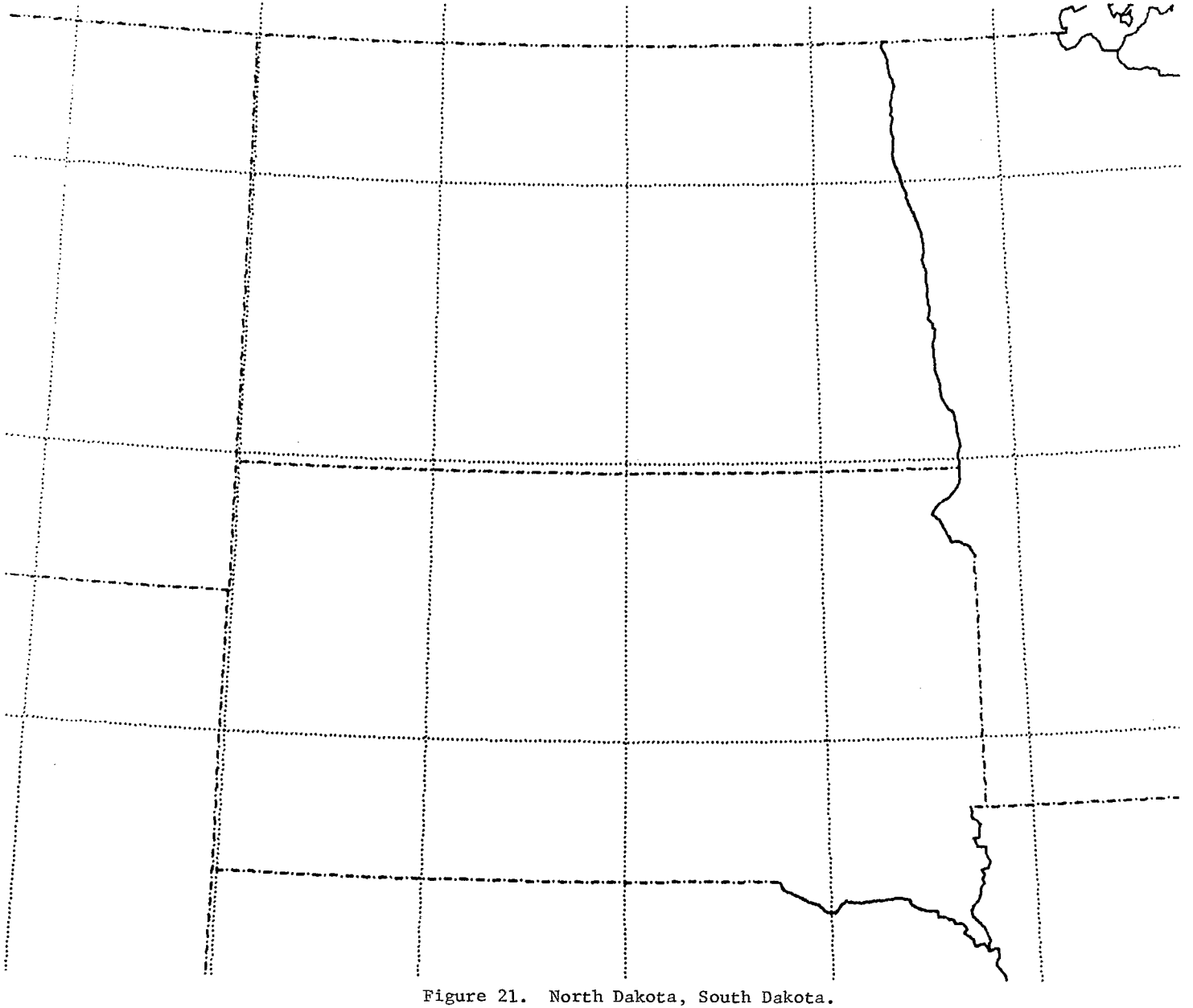


Figure 21. North Dakota, South Dakota.

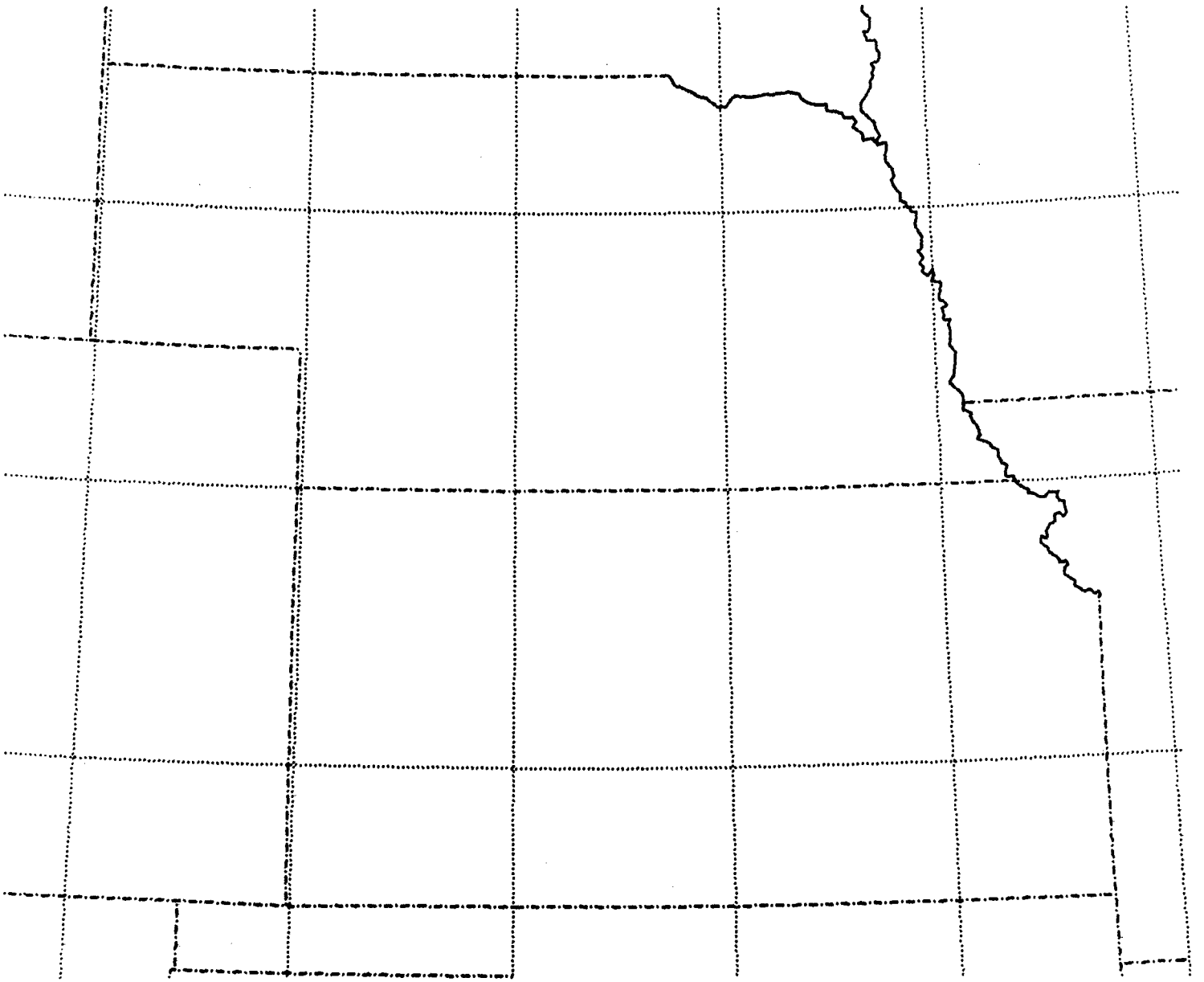


Figure 22. Nebraska, Kansas.

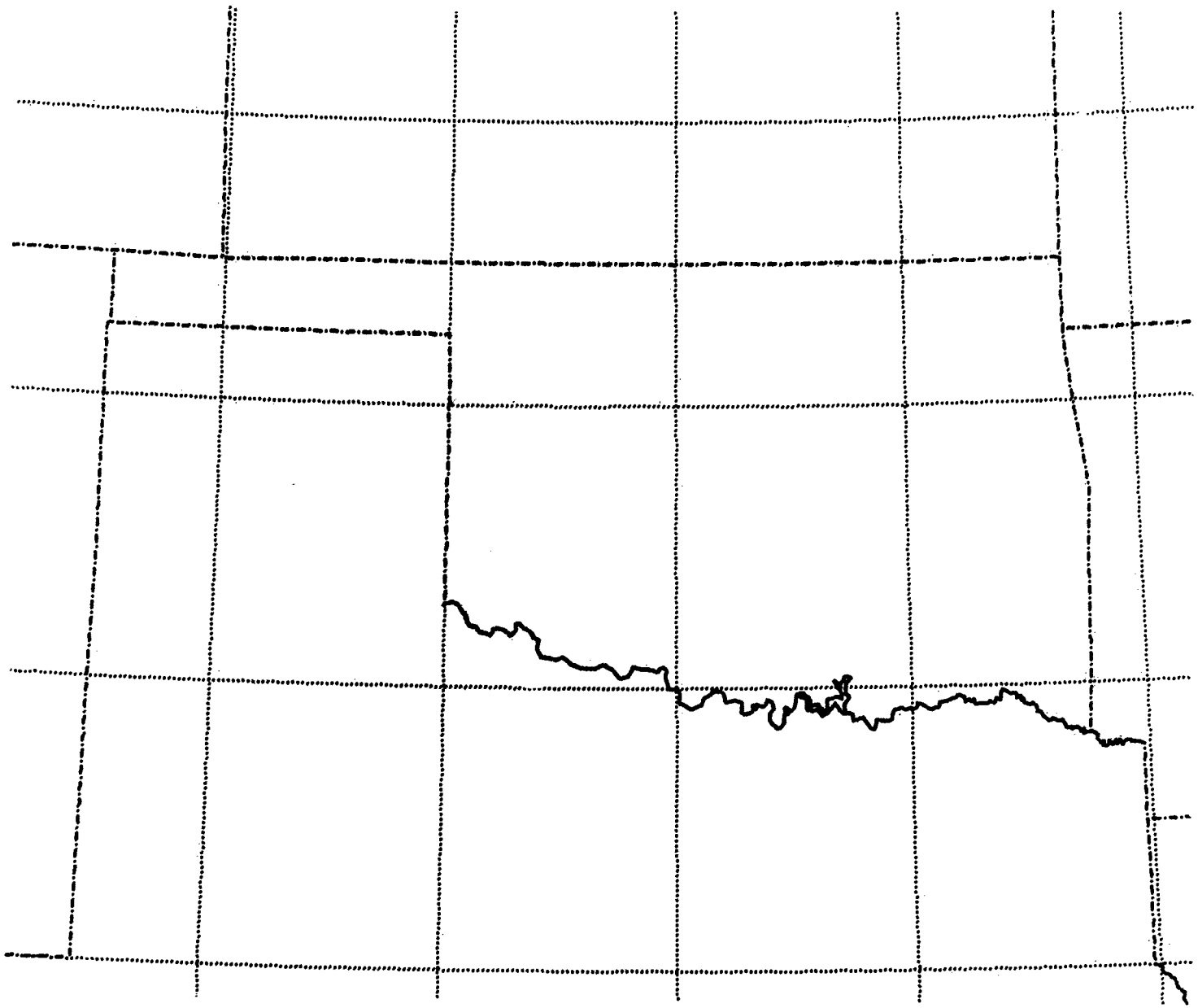


Figure 23. Oklahoma.

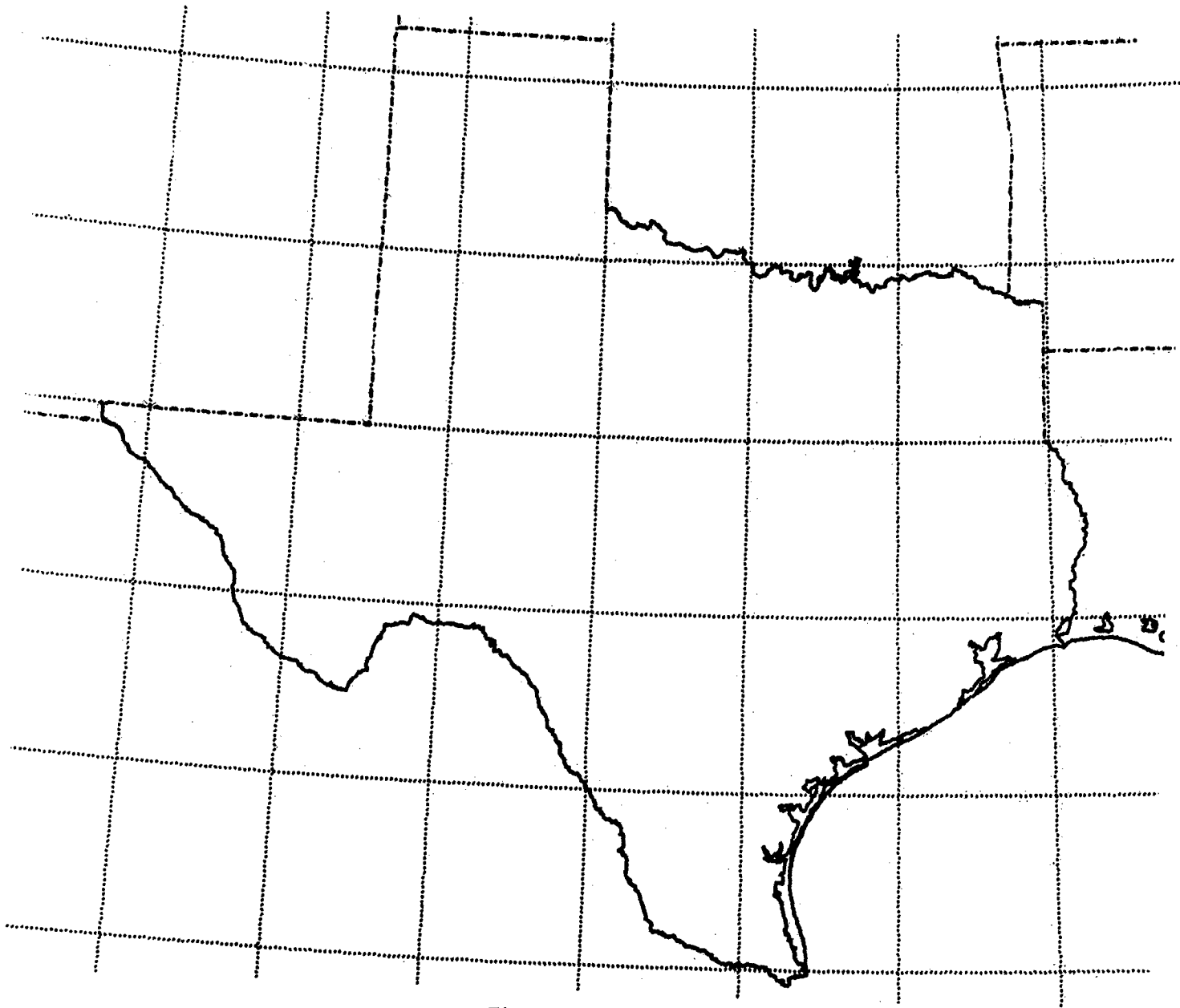


Figure 24. Texas.

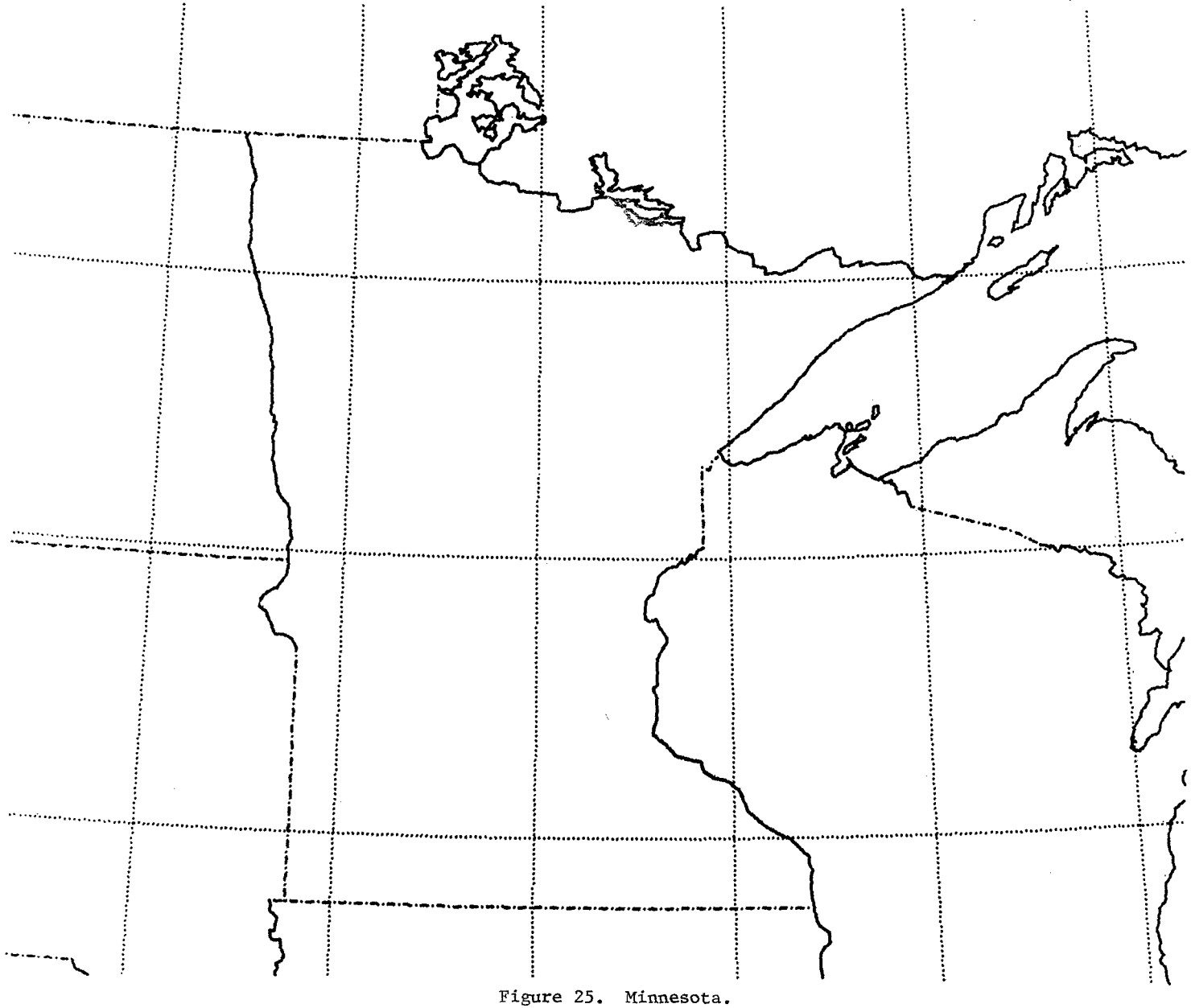


Figure 25. Minnesota.

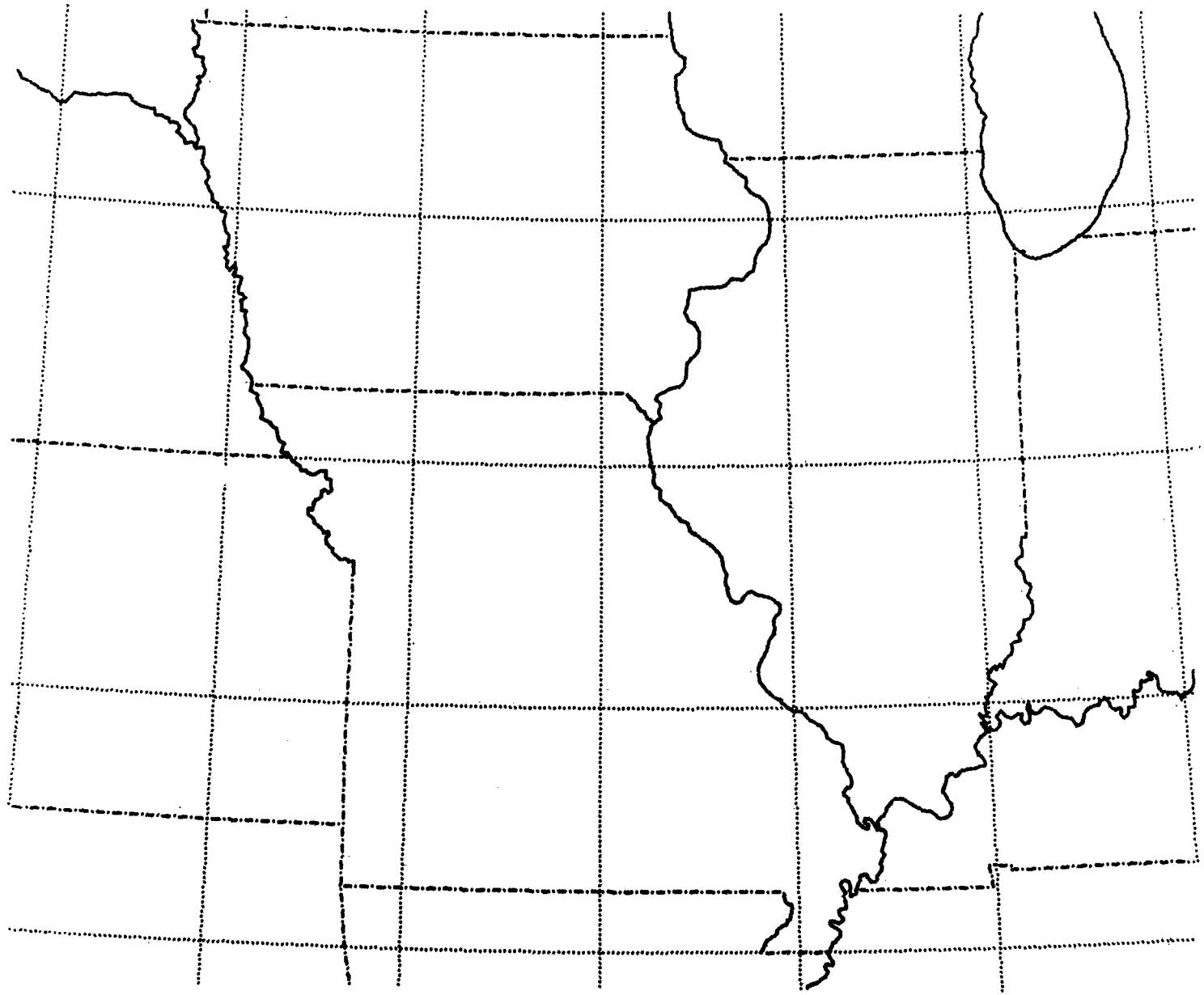


Figure 26. Iowa, Missouri, Illinois.

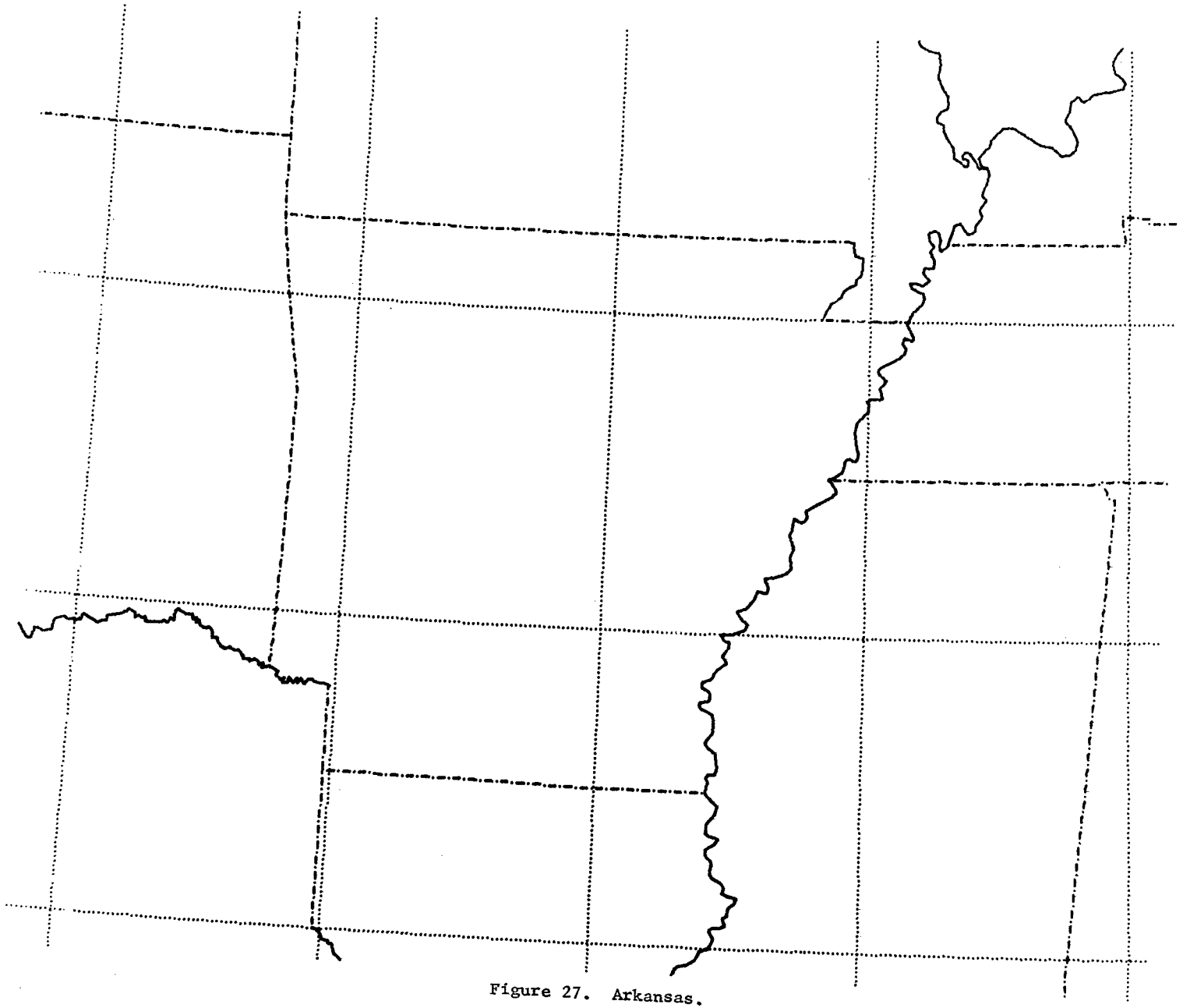


Figure 27. Arkansas.

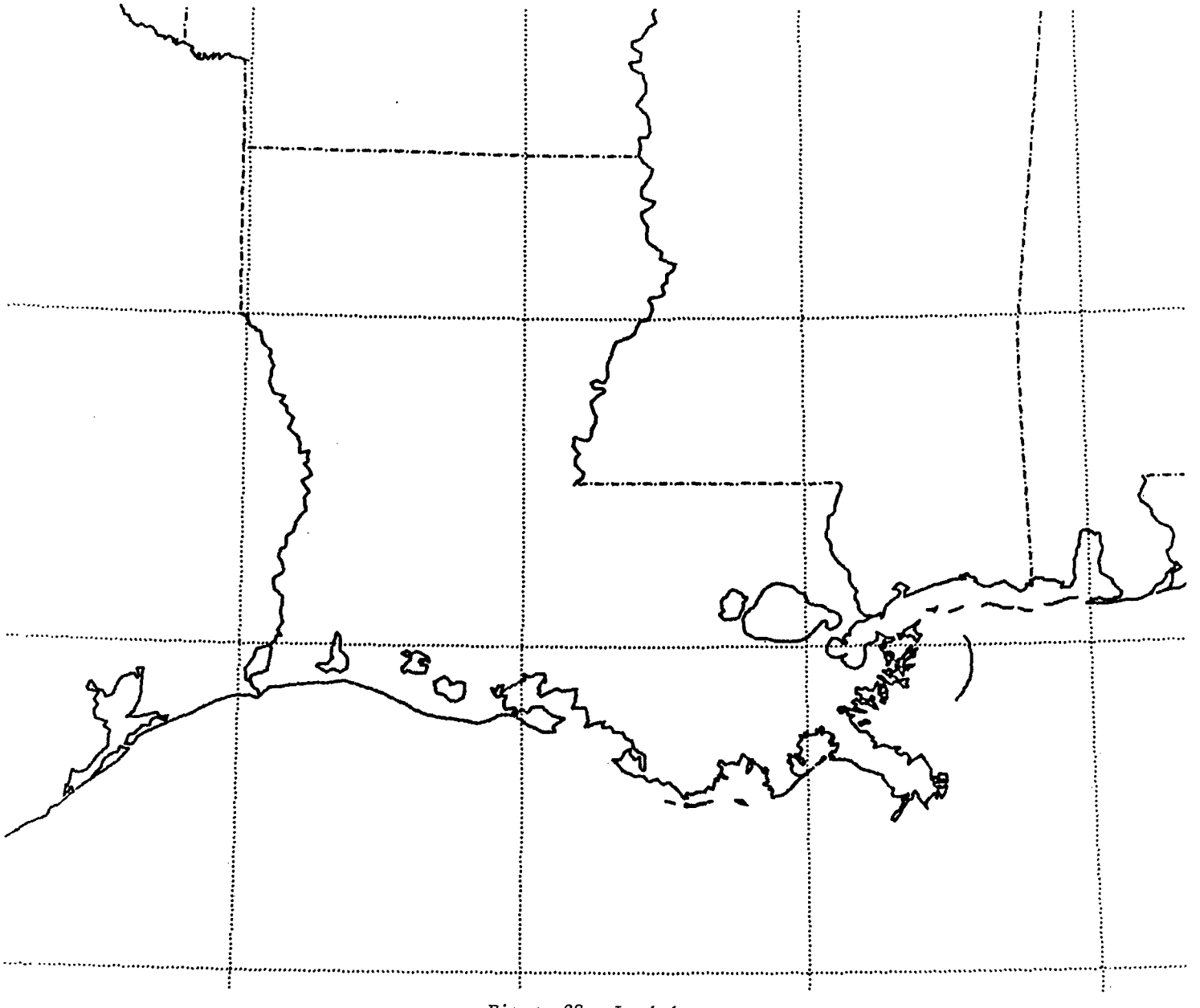


Figure 28. Louisiana.

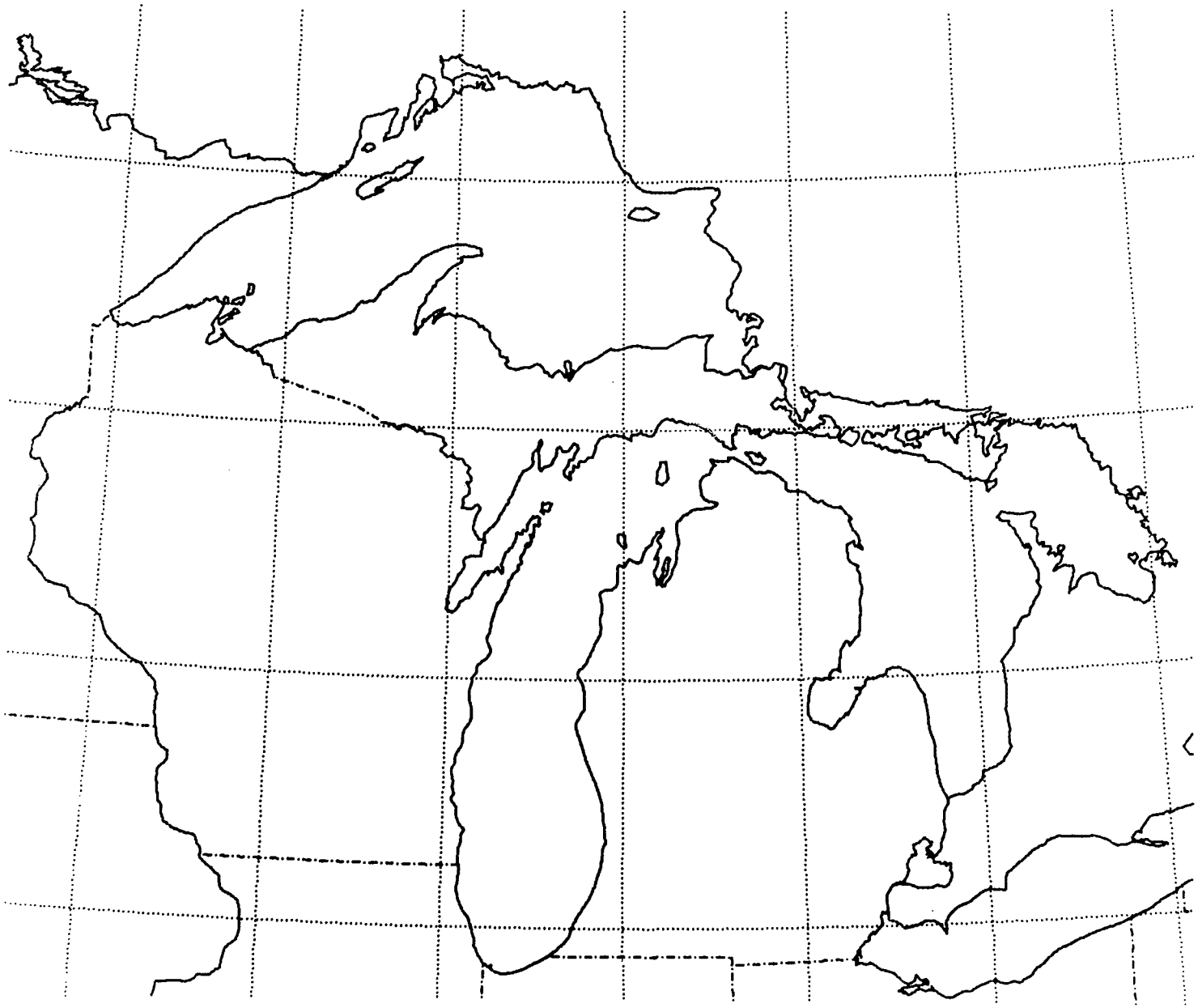


Figure 29. Wisconsin, Michigan.

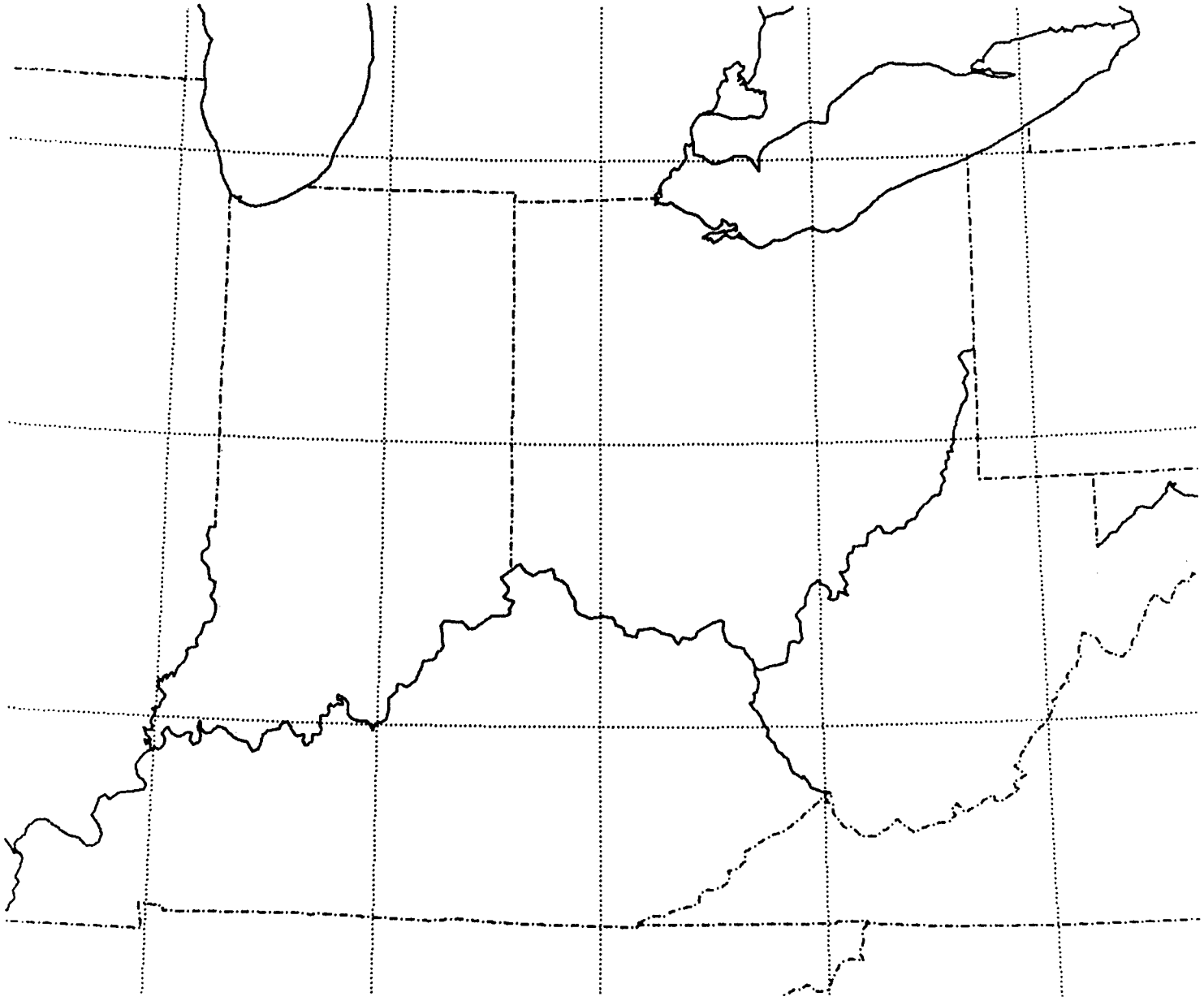


Figure 30. Indiana, Ohio, Kentucky.

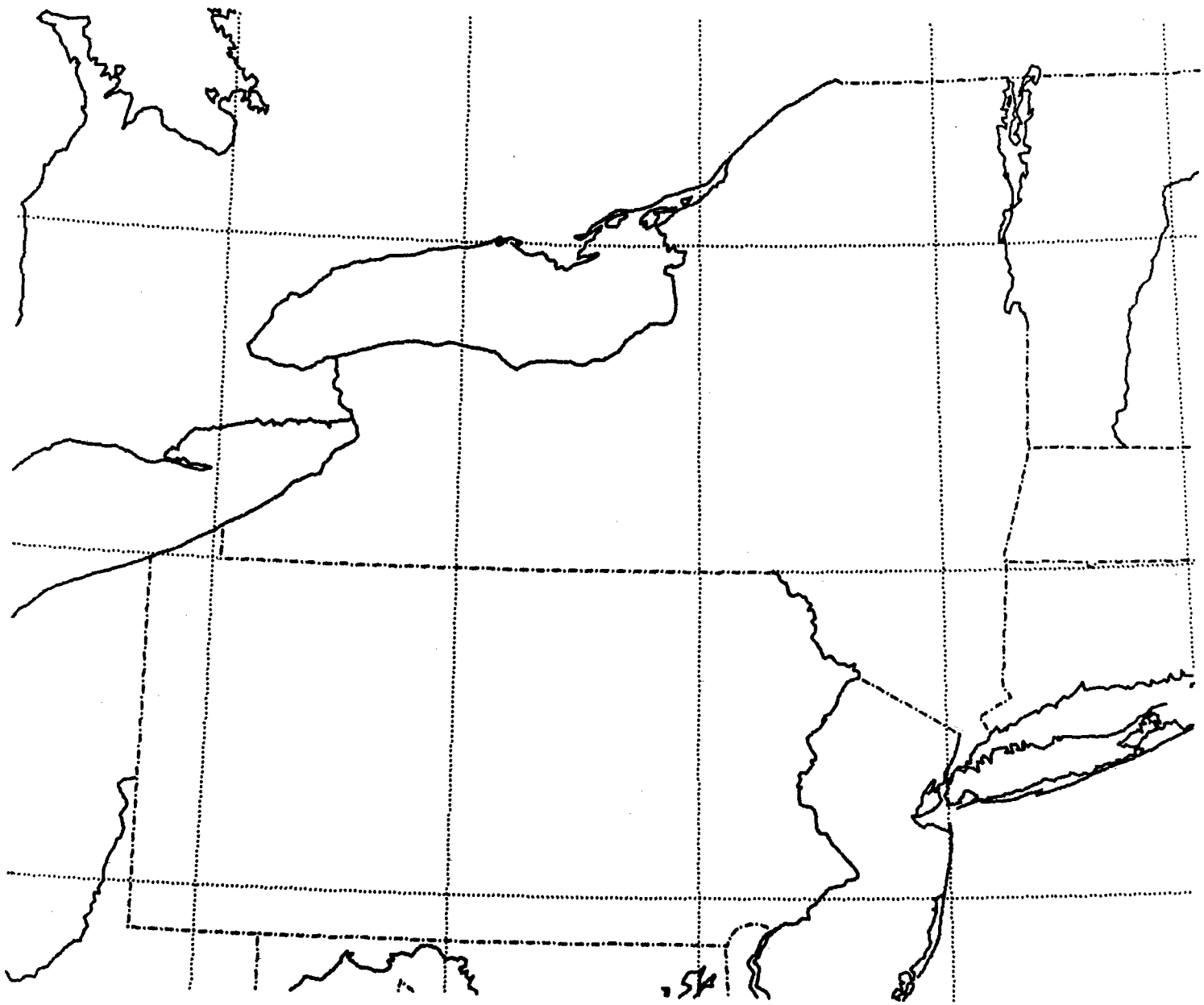


Figure 31. New York, Pennsylvania.

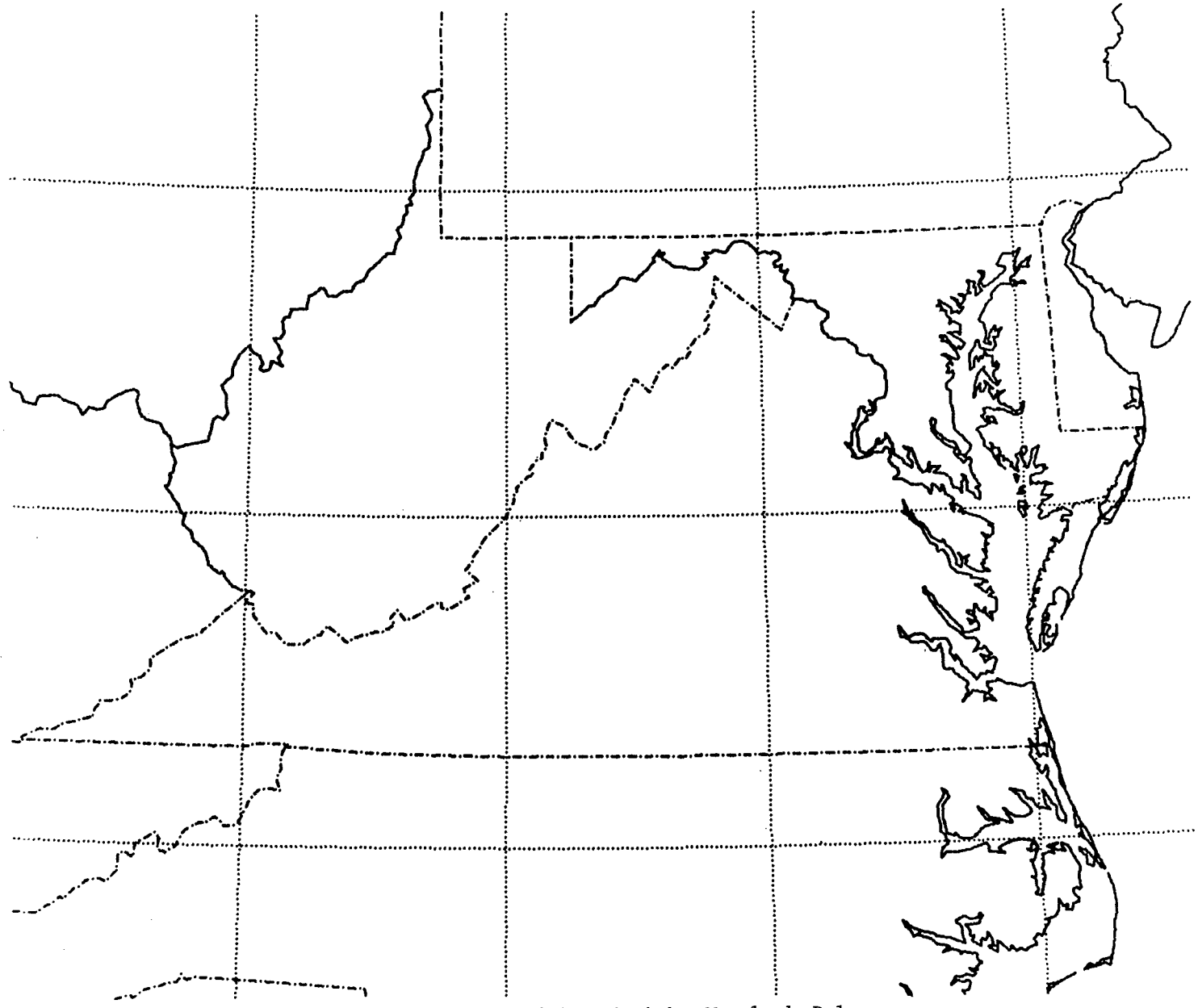


Figure 32. West Virginia, Virginia, Maryland, Delaware.

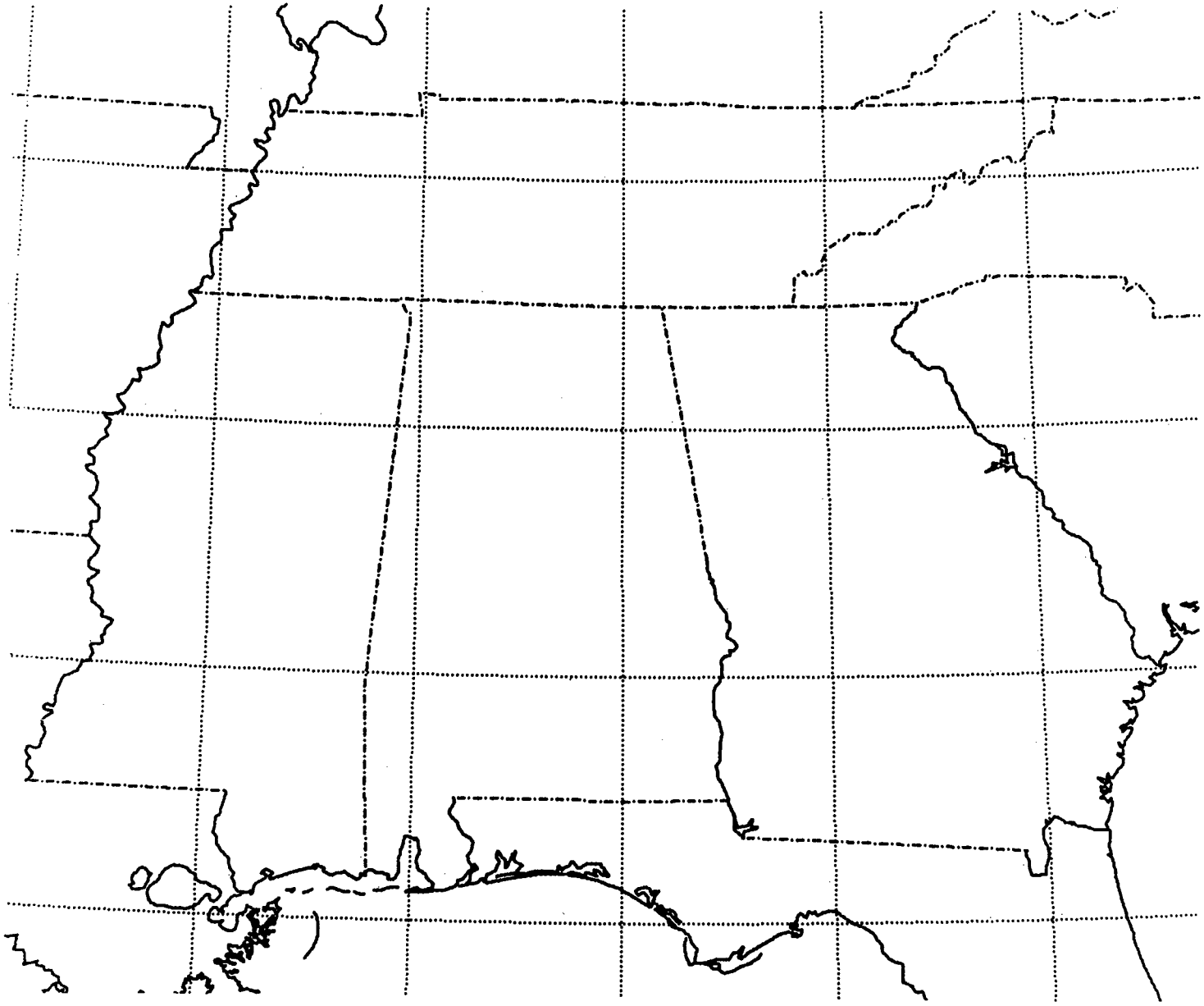


Figure 33. Tennessee, Mississippi, Alabama, Georgia.

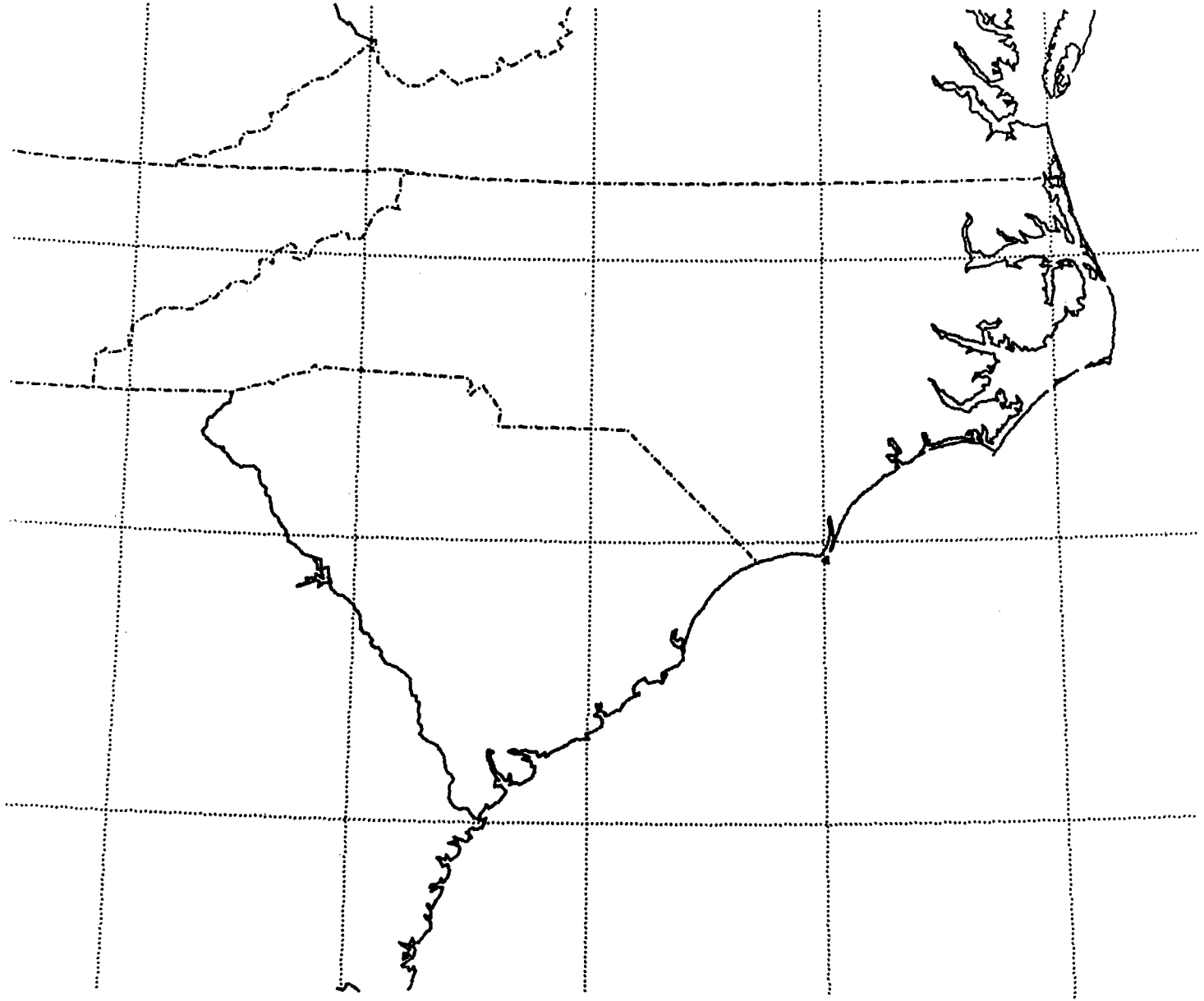


Figure 34. North Carolina, South Carolina.

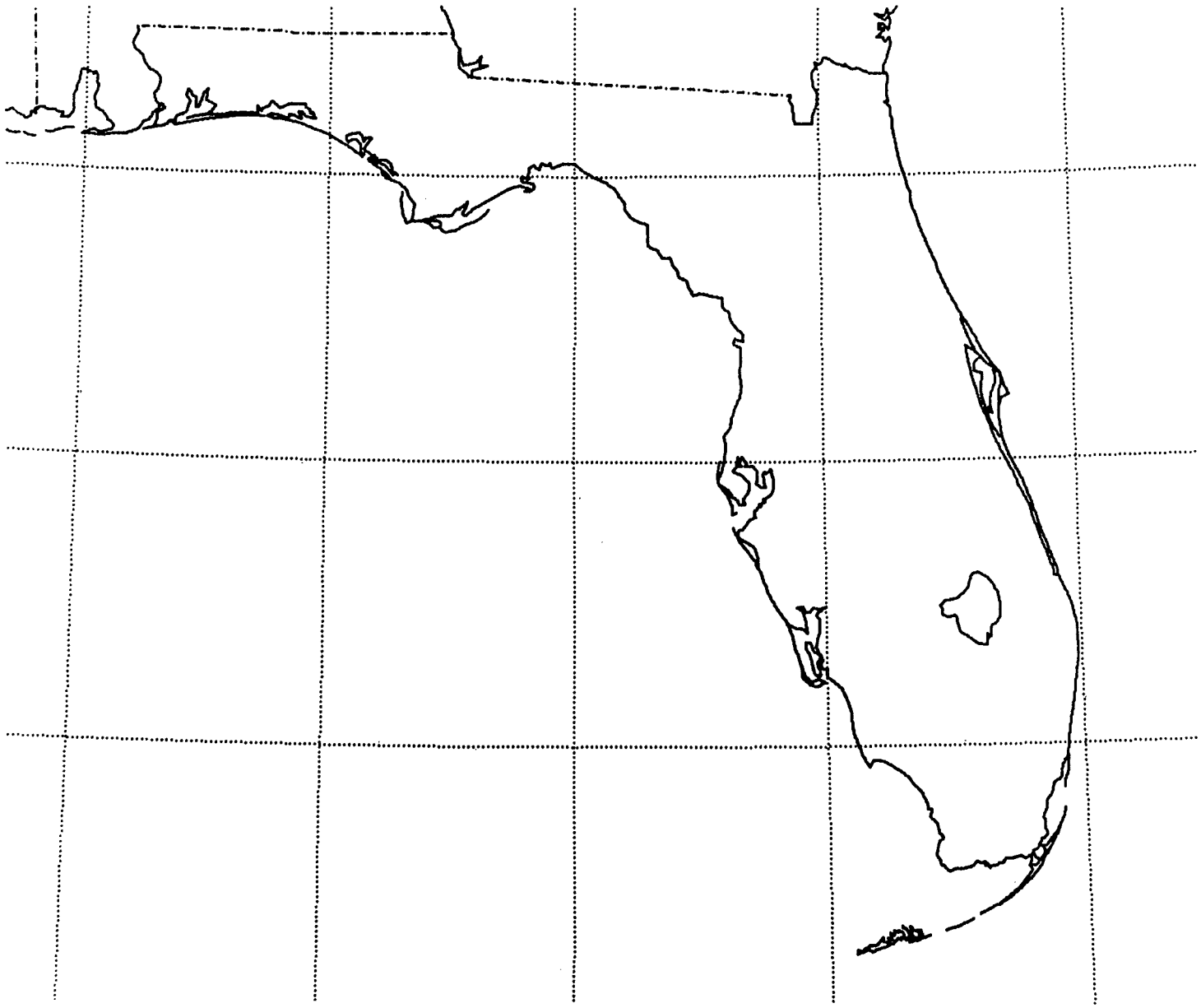


Figure 35. Florida.

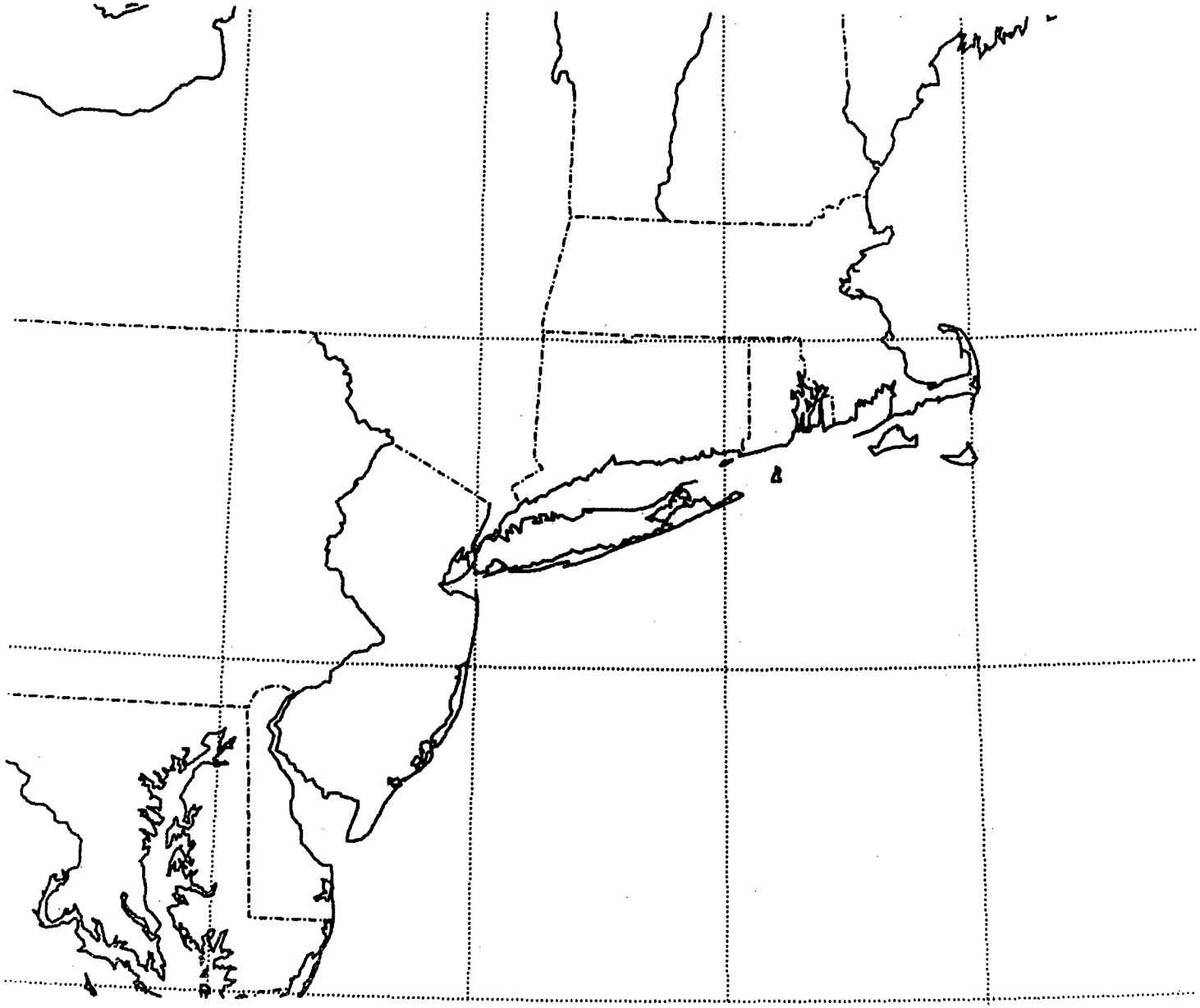


Figure 36. Delaware, New Jersey, Connecticut, Rhode Island, Massachusetts.

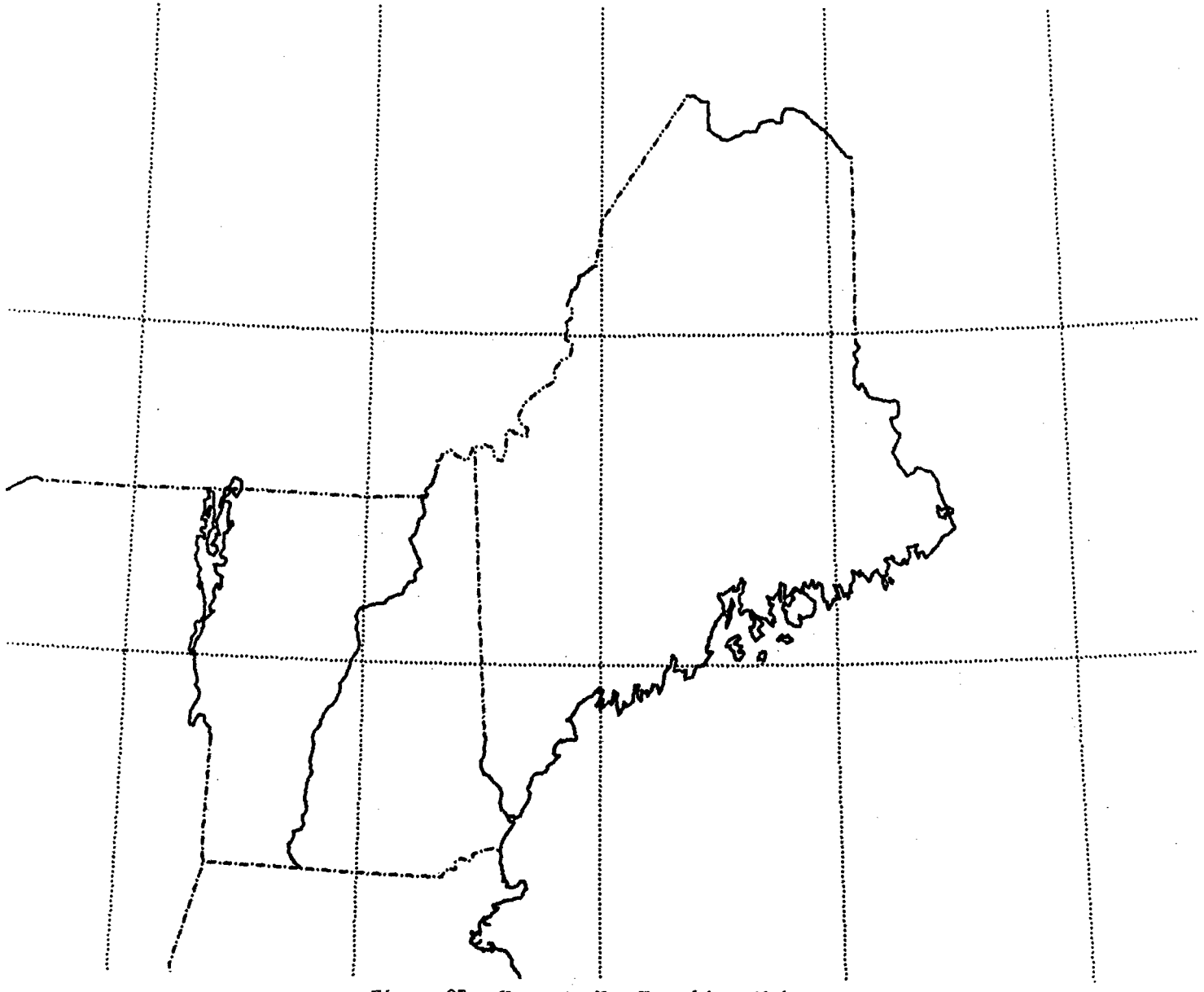


Figure 37. Vermont, New Hampshire, Maine.

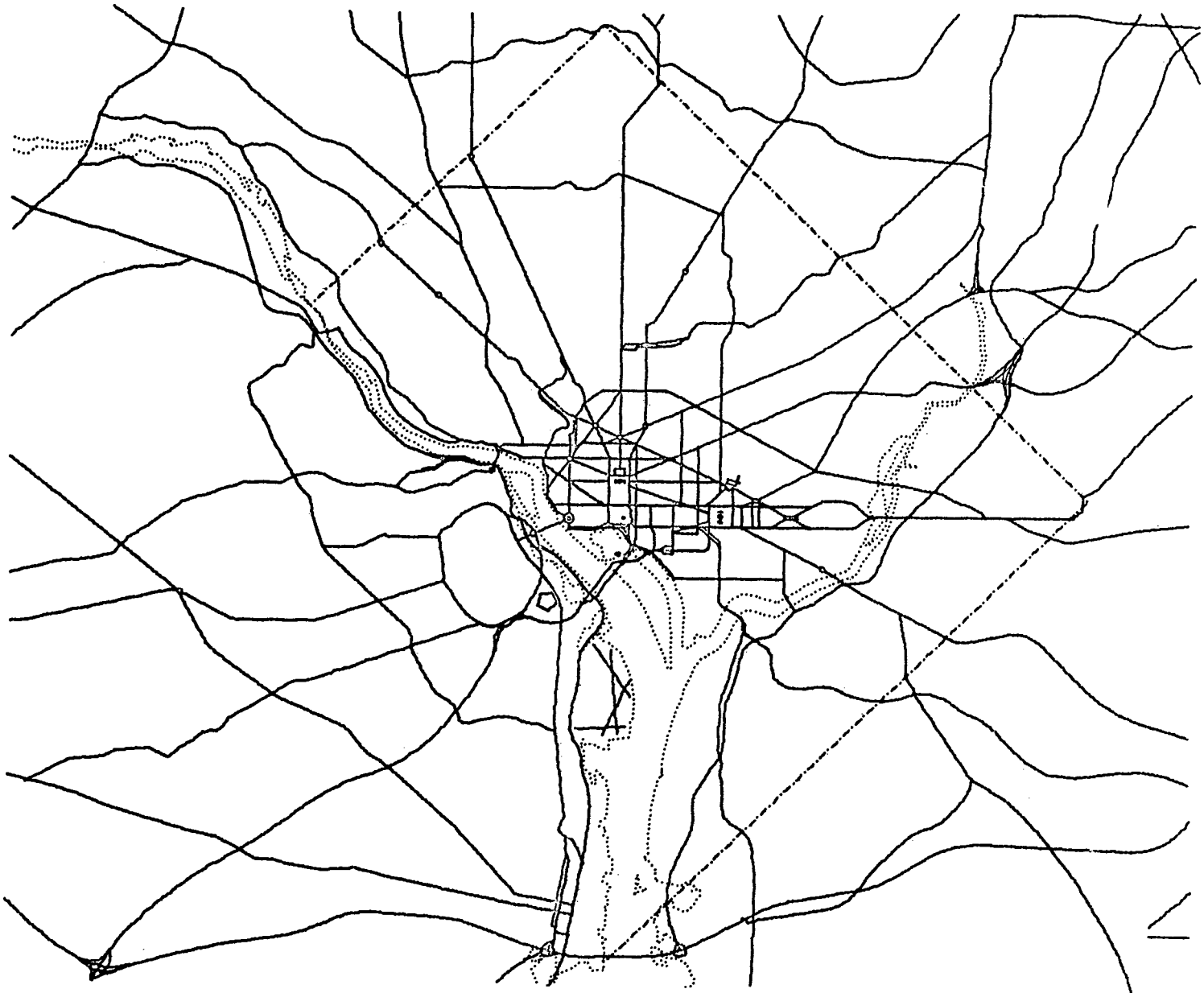


Figure 38. District of Columbia.

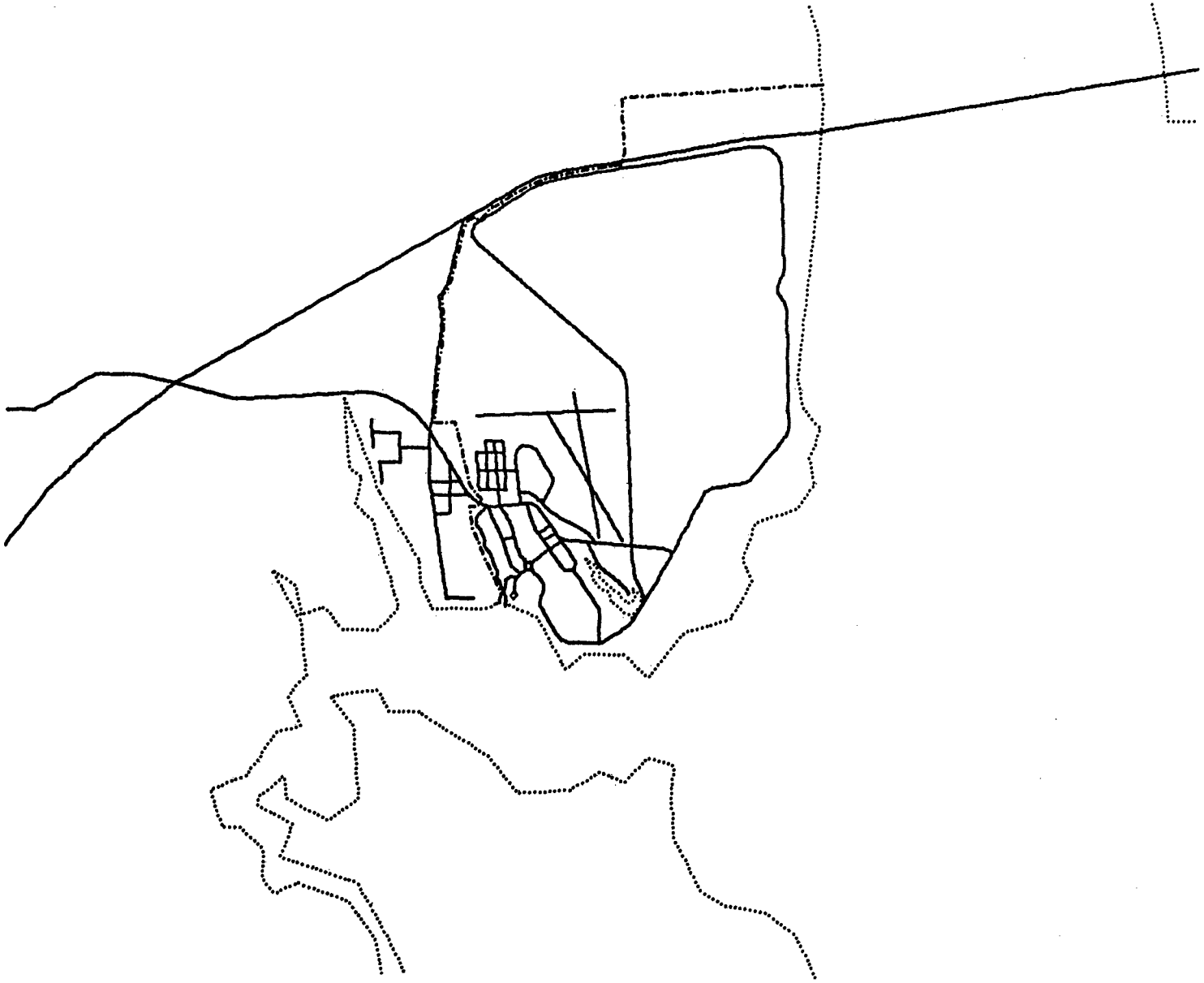
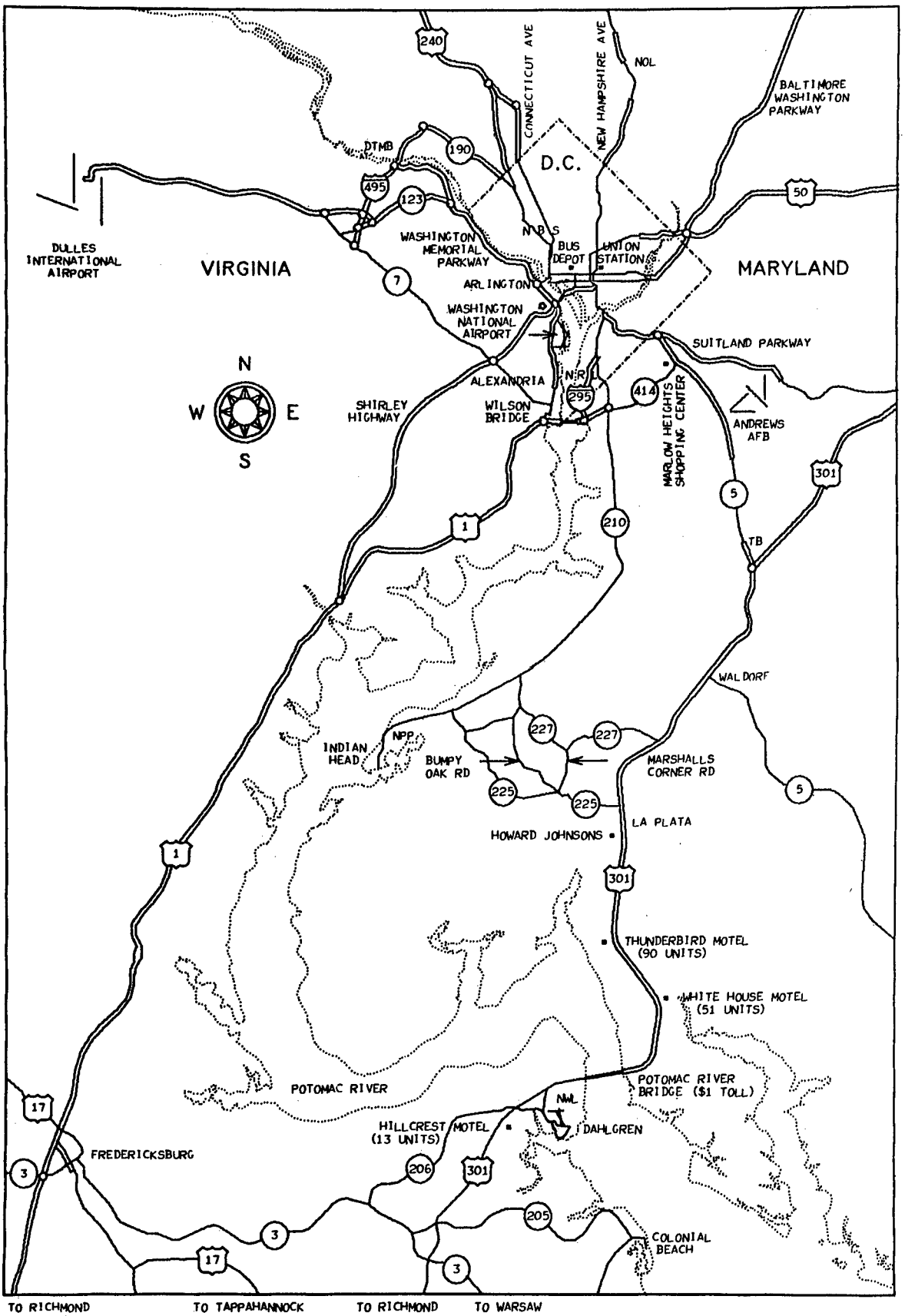


Figure 39. Dahlgren.



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2 LANE HIGHWAY
4 LANE HIGHWAY
INTERCHANGE

0 5 10
MILES

DAHLGREN, VA.

17 JANUARY 1963

Figure 40.

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